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A NEW SPANISH PORTLAND CEMENT WORKS.

A Portland cement works, with a capacity of 1,000 barrels per day, has recently been completed by American engineers and equipped with American machinery for the Compania General de Asfaltos y Portland, of Barcelona, Spain. This new works, while not of great capacity judged by American standards, possesses the novelty of being operated entirely by water power. The machinery is divided into nine separate groups, and each group of machinery is operated by a separate water wheel, all of which take water from the same penstock and discharge into the same tailrace pipe. The water as it enters the works on level No. 1 has a head of 890.8 ft., and at the lowermost wheel, No. 7, it has a head of 1,052.47 ft. These heads come well up among the highest in the world and give additional interest to the installation.

The location of the works is about 80 miles from Barcelona, at a point where a fall in the River Llobregut gives an available water power of 2,100 HP. for the greater part of the year, and where, also, there are vast deposits of argillaceous and carbonate rock suitable for cement manufacture. The chief drawbacks of the location were its distance from Barcelona, the nearest seaport, and the necessity of constructing about 25 miles of new railway to connect the works with the nearest station. This new railway was secured by extending the existing railway 17½ miles and building about 7½ miles of government and private road to connect with it, but it was not completed in time to get the construction materials to the site of the mill, and they had all to be hauled by mule trains and traction engines.

GENERAL VIEW OF CEMENT WORKS OF THE COMPANIA GENERAL DE ASFALTOS Y PORTLAND, OF BARCELONA, SPAIN.

A general view of the plant completed to half its projected size is given by Fig. 1; as will be seen by the stacks, only three kilns of the total of six are installed. The remaining three kilns will be set in line with those installed, and, in fact, the remaining buildings and plant to be constructed will duplicate those already installed, which may, therefore, be considered to complete the plant up to the center plane along the longitudinal axis. As completed, the building is divided by a longitudinal wall into two bays; the outside bay being occupied by the coal mill and machine shop and the other by the cement mill proper. The total width of the completed building is 116 ft. and its length is 395 ft.; it has a variable height of from 25 ft. to 30 ft. The walls are built of rubble masonry 24 ins. thick, and have buttresses to carry the roof trusses, which are also supported by intermediate columns along the center line of the cement mill. The trusses and columns are of wrought iron. The roofing is Guastavino tile arches covered with paroid roofing.

For manufacturing purposes the building is divided into raw material, calcining and cooling, clinker grinding, storage and packing, and coal grinding departments. The raw material department is located at the up-hill end and the calcining, grinding and packing departments follow in order descending the hill. The course of the cement material is as follows: Entering the uppermost level of the mill, the blasted rock is given its first reduction in a No. 5 D Gates crusher, and its second reduction in a set of Fraser & Chalmers 36 × 16-in. crushing rolls. The crushed stone is then dried in a 54-in. × 40-ft. rotary drier, from which it is fed in succession into a No. 8 ball mill and a 5-ft. × 22-ft. tube mill. The layout of this machinery is shown by Fig. 2.

As will be seen, the crusher spouts its output directly into the rolls, which in turn feed to the drier by means of a screw conveyor. From the drier a screw conveyor takes the stone to the ball-mill hopper and the ball mill spouts its product into the tube-mill hopper. The tube mill feeds the ground raw material by means of screw conveyors into the storage tanks of the rotary kilns. The machinery layout is of interest chiefly in showing the arrangement of the water wheels and the belt drives from them to the various machines. There are two water motors in this department, one of 220 HP., running at 540 r. p. m., for driving the crusher, rolls and drier, and one of 350 HP., running at 300 r. p. m., for driving the ball and tube mills and their conveyors. The arrangement of the shafting and the belt drives and the space that they occupy are clearly shown by the drawings. Another feature of this plan which deserves notice is the water supply and tailrace pipes and connections.

The supply main comes into the mill at right angles to its axis, as is indicated by Fig. 1; it then bends and passes through the mill lengthwise and just inside of the longitudinal division wall previously mentioned. As shown by the plan, Fig. 2, branches from this supply pipe lead to each wheel. The discharge from the wheels lead to a tail pipe, which is located in the same plane and beneath the supply pipe. This discharge pipe starts with a small diameter at wheel No. 1 and increases in size as each succeeding wheel adds its quota of water. The supply pipe, on the other hand, decreases in size as it proceeds through the mill. It should be noted also that the machinery described is, owing to the side-hill site of the works, located on different levels. This feature is quite clearly shown by Fig. 3.

The plan, Fig. 2, shows the course of the raw material as far as the storage tanks for the rotary kilns. There are three of these, each one 6 ft. in diameter and 60 ft long. They are all driven by belts from the water wheel shaft, which extends across the building underneath them. The water wheel is of 70 HP., and runs at 560 r. p. m.; its shaft is belted to a transverse jack shaft under

each kiln, which drives the kiln by bevel gears and also carries a pulley which is belted to the screw-feed device. The kilns discharge into three Mosser coolers set beneath them on the level below, and at this level is also set the water wheel which drives the blowers for the coolers and for feeding the coal to the kilns. This water wheel is of 80 HP. and runs at 400 r. p. m.; the blower plant, which is operated by this wheel, comprises a 70-in. rolling-mill blower, furnishing cold air to the coolers and two special upblast gas blowers for feeding the pulverized coal to the kilns. It should be noted here also that the system is so arranged as to use the hot air from the coolers in connection with the feeding of the pulverized coal into the kilns.

From the coolers the clinker is elevated and conveyed to a hopper over the ball mill, which accomplishes the first stage in the reduction of the cement. The ball mill is a No. 8 mill, and its product is handled by two 5-ft. × 22-ft. tube mills, which discharges directly into the conveyors leading to the storage bins. The ball mill and tube mills are driven by a 550-HP. water wheel, running at 300 r. p. m. The storage bins are two in number, and they feed into the hoppers of the barrel packers. The packing house machines are operated by a 35-HP. water motor, running at 1,160 r. p. m.

The coal-grinding plant occupies the side building adjacent to the main cement mill, as is indicated by Fig. 2. It consists of storage bins, crushing rolls, driers and tube mills in succession. The crushing rolls are 18 × 24 ins., and the drier is of the rotary type and is 4 × 35 ft. in size. The tube mill is 5 × 22 ft., and its product is conveyed directly to the rotary kiln coal hoppers. The coal-mill machinery is operated by a 220-HP. water wheel, operating at 450 r. p. m. On level 13 in the lower part of the coal-mill building, and entirely isolated from the same, is placed an 85-KW. direct-current General Electric compound wound generator for furnishing light for the mill and adjoining houses; also a 22¼ × 14¼ × 16-in. Class J Ingersoll-Sergeant compressor for furnishing compressed air for the D24 Ingersoll-Sergeant rock drills, as well as for minor other purposes in the repair shop. The generator and air compressor, which are both belt-driven, are actuated by a 350-HP. water wheel running at 450 r. p. m.

In connection with the mill, there will be a repair shop equipped with a large and small lathe, planer, radial drill, shaper, drill presses and other smaller machines for making the necessary repairs to the machinery.

When work was started in the mill the nearest railway station was 25 miles distant. In order to transport the machinery and pipe line and prepare an outlet for the product of the mill, an extension of the railroad for 17½ miles and the construction of 7½ miles of government and private road were necessary. As it was necessary to begin transporting machinery before the railroad was entirely finished, it was decided to use a "Best" traction engine, made in California. For this work several small pieces of temporary road, including four crossings of the river by ford, were used in connecting those parts of the railroad cut and fill that had been finished. Fig. 4 shows the traction engine fording the river with wagon load of cement machinery. Fig. 5 shows the train loaded with two tube mills, one clinker cooler shell, one kiln section and two sections of rotary drier nested within the tube mills, in all weighing 28 tons, or a total load of 40 tons, including wagons.

In transporting the pipes for pipe line from the mill to their positions along the line, special roads were necessary. Grades up to 18% were used on

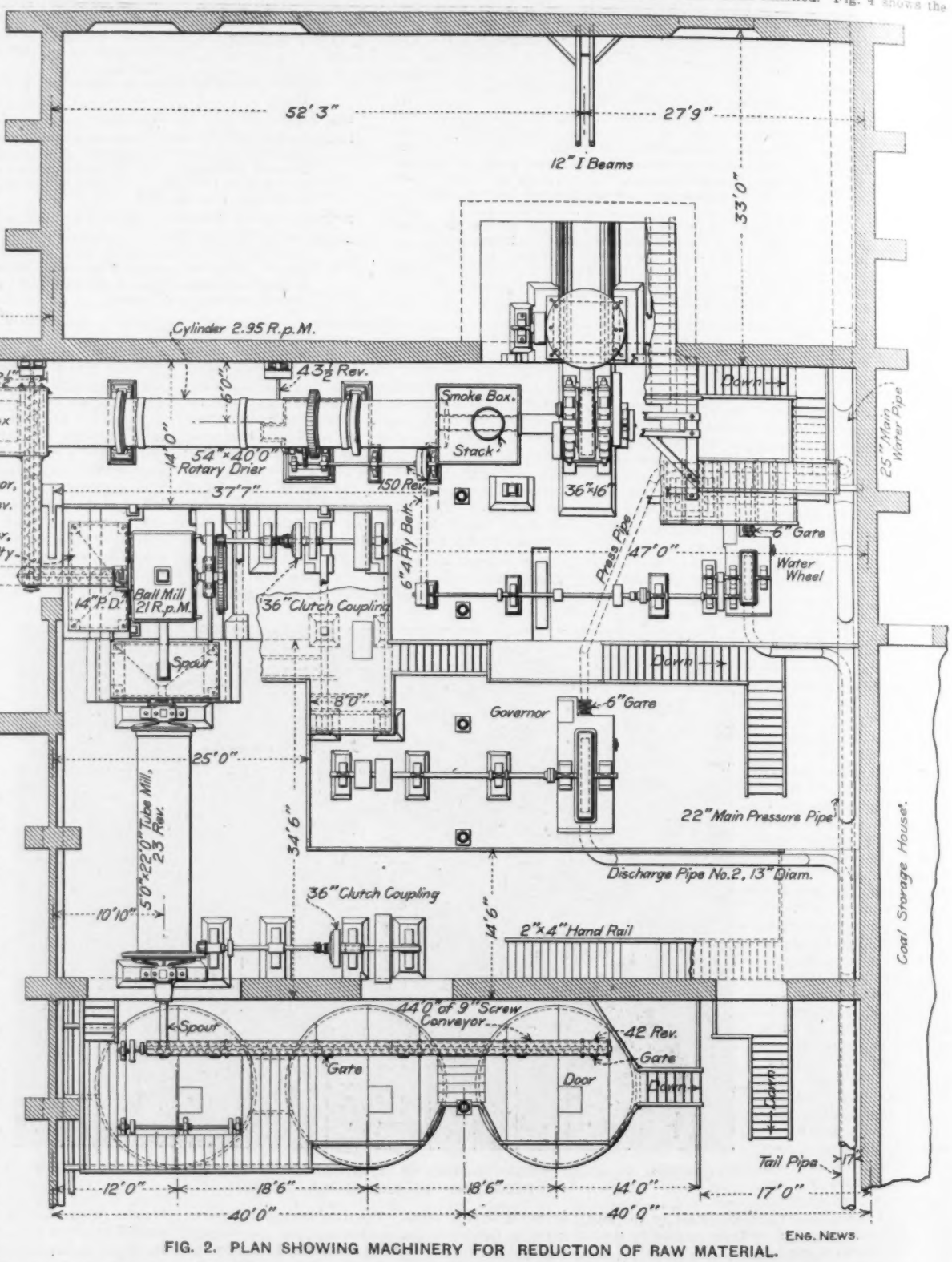

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FIG. 2. PLAN SHOWING MACHINERY FOR REDUCTION OF RAW MATERIAL.

these roads. The form of truck used was the same as is used in the transportation of water and gas mains in city work, having the axle curved to take the pipe. One feature of this truck that was found convenient was the design and length of the pole. This was made one-half the length of the common pipe, 10 ft., less the thickness of the average pipe flange, and had two angles, one fixed to either side, with slot holes in the legs next the pipe flanges. The bolt holes in the pipe flanges were utilized to secure the end of pole to the length of pipe. This construction, with the usual chain grip at the axles, insured the balancing and rigidity of load. The hauling was done by five and six mules, a "tiro" of mules, one ahead of the other, as is customary in Spain, and all is clearly shown in Fig. 6.

The properties of the company named, including the asphalt, cement rock, limestone coal and forest claims, are very extensive, there being sufficient raw material to last for centuries. The natural and mechanical advantages possessed insures, it is thought, that the cost of production of cement will be such as to guarantee a greater consumption of Portland cement in Spain and lead to the further development of high grade cement manufacture. Inquiries have been received from India, Egypt, South America and from the Spanish Government engineers about the use of the cement.

The capitalization of the company, according to the articles of incorporation, is given at 2,500,000 pesetas, or $357,000. When the work is finished the total investment will be somewhat more than double this amount. Unlike many other industries and mining holdings of importance in this country, the capital of the company is entirely held by Spaniards. The officers are: Senor Don Eusebio Güell, President; Marquis of Comillas, Vice-President; Senor Don Luis Ferrer Vidal, Gerente (manager); Senor Don Juan Jose Ferrer Vidal, Vice-Gerente, and Senor Don Ernesto Moline.

The engineer for the works was Mr. W. W. Ewing, formerly Engineer, Department of Buildings, New York city, and now located at Barcelona, Spain, as engineer in charge of the works of the Compania General de Asfaltos y Portland. The contractors for the water wheels and other hydraulic plant were the Pelton Water Wheel Co., San Francisco, Cal., and the contractors for all of the cement mill and other machinery were the Allis-Chalmers Co., of Chicago, Ill. We are indebted to the engineer and contractors for the information from which this description has been prepared.

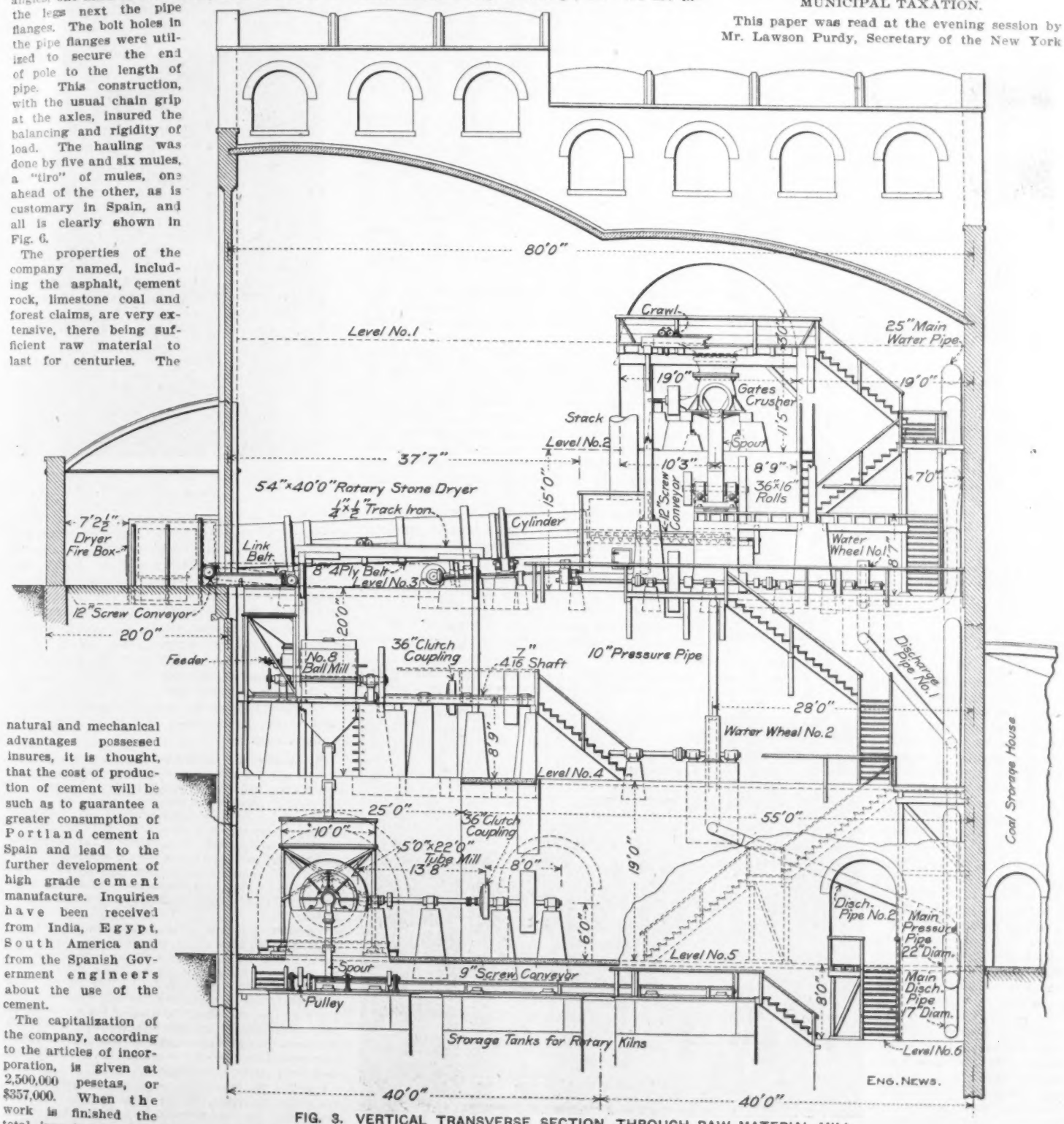


FIG. 3. VERTICAL TRANSVERSE SECTION THROUGH RAW MATERIAL MILL.

ANNUAL MEETING OF THE NATIONAL MUNICIPAL LEAGUE.

The tenth annual meeting of this association was held in Chicago April 27, 28 and 29, the sessions being held in the Northwestern University Building and in Cobb Hall of Chicago University. After the formal opening addresses, in the afternoon of April 27, a report covering the development in municipal good government affairs during the year was read by the Secretary, Mr. C. R. Woodruff. The election of officers was then taken up and the full list of officers and directors were re-elected. Mr. Charles J. Bonaparte, of Baltimore, Md., is President, and Mr. Clinton Rogers Woodruff, of Philadelphia, is Secretary.

MUNICIPAL TAXATION.

This paper was read at the evening session by Mr. Lawson Purdy, Secretary of the New York Tax Reform Association. It dealt with general as well as municipal taxation, and from it we take the following extracts:

At least part of the state revenue should always be raised by an elastic form of taxation which can be increased or diminished in accordance with the need for revenue, and whose incidence will be felt by the taxpayers. Such an elastic system was proposed four years ago by the New York Tax Reform Association, and endorsed by the New York Chamber of Commerce and other bodies. It provides for the apportionment of so much

state revenue as may be required in excess of that derived from special taxes, to the several counties of the state in proportion to the revenue raised for all purposes by and within each county. By this plan, if the total local revenues amount to $100,000,000, and the local revenue of a certain county amount to $1,000,000, that county would contribute 1% of whatever amount the state may need. This plan was adopted in Oregon in 1901, but the Oregon law is unjust in that the apportionment is based upon county revenue and not upon the revenue of each county and all the taxing districts within it. The result is that the rich counties will pay less than before, and the poor

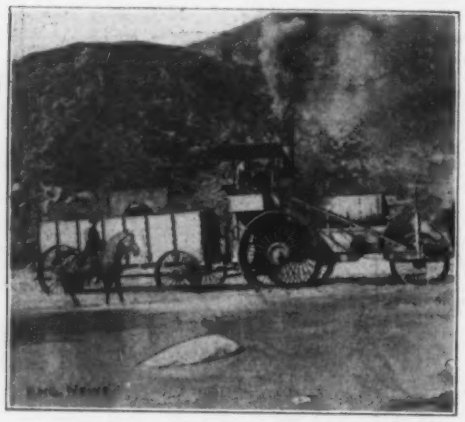


Fig. 4. Traction Engine Fording Stream with Load of Cement Machinery.

counties more. The tendency to economical administration of local affairs which would result from the apportionment of state taxes on the basis of local revenue is a desirable feature of this method of apportioning the burden of supporting the state. In the state of New York all the expenses of the state are only about 15% as much as the total expense of supporting local governments. There are very few states in which more than $1 in $7 is required for state purposes, and in many states a large part of the state revenue is now raised by special taxes.

The chief source of local revenue is now and always will be the taxation of real estate, which now pays from 75% to 99% of all local revenue. On this account alone it is of the utmost importance that the assessment of real estate should be as nearly equitable as human machinery can make it. The prevailing practice of disobedience to the law which requires assessment at full value, or market value, or cash value, renders an equitable assessment an impossibility. After a long struggle the policy has been adopted in the city of New York of assessing real estate as the law directs, and in spite of an insufficient appropriaton and a very inadequate number of assessors, the improvement effected in two years has been tremendous. One year ago a further improvement was adopted, requiring the assessors to state separately the value of each parcel of land exclusive of improvements. This has been in practice for many years in Massachusetts and a few other states, but while in other states the land value is separately stated, the improvements are also separately stated. In the City of New York we have only two columns of the record for values, in which are set down the land value and the total real estate value. This is an economy of clerical labor, and we believe positively exerts an influence on the assessors to keep them from over-valuing buildings.

A still further improvement was effected by an amendment to the city charter which requires publication annually of the complete record of real estate assessments. Publication will be made by sections, into which the city is divided for purposes of assessment. Each section contains from 10,000 to 30,000 parcels, and will be published separately; and persons interested can buy for a few cents the assessment roll of one or more sections, or of the whole city. This will render comparisons very easy, and disseminate knowledge of assessed values which will tend towards constant improvement in the accuracy of the assessments.

The slow progress we are making in reforming methods of taxation is due far more to ignorance than to any conflict of interests. Men in the country want to tax the rich man, and go about it in a way that is quite unsuccessful, and recoils with redoubled force upon themselves. Even in cities, any demagogue who for the moment gets the ear of the people can get temporary popularity for schemes to tax department stores, to tax reserves of insurance companies, and other forms of wealth or agencies of trade or commerce. Every tax on the products of human labor or upon the processes of trade falls inevitably on the people in proportion as they consume; that is, such taxes are a burden inversely proportioned to the family income. What we need is smaller constituencies to educate, and object lessons which will educate the rest of the people by sheer compulsion.

CONCLUSION.—In conclusion I will sum up the steps which lead to the shortest, easiest way to improve our local tax systems: (1) Abolish all constitutional restrictions on the power of the legislature to regulate taxation; (2) do away with the necessity for uniform state taxation by apportioning state taxes in proportion to local revenue; (3) give to every county the right within the general laws of the state to exempt from taxation any class of property, or to proportionately reduce the assessment of any class of property; (4) assess real estate annually, state the value of land, separately, and publish the assessment rolls in a convenient form.

The discussion turned particularly on the taxation system in Chicago, the complications and difficulties of which were explained by Mr. C. C. H. Fyffe, Assistant Corporation Counsel, and Mr. E. A. Frost, ex-controller. The city has a number of taxing bodies, which raise and spend taxes independently of the city. As an instance, the new State St. bridge was cited. The city had no money to pay for it, but the Sanitary District had plenty of money and built the bridge as part of the improvement of the river in connection with the drainage canal. But it is a city bridge, watched by the city police and controlled by the city's harbor-master.

MUNICIPAL NOMINATION SYSTEM.

On the morning of April 28, there was presented a draft of a proposed municipal nominating law, which was explained by Mr. Horace E. Deming (New York), chairman of the Committee on Nominating Reform. One feature is that a petition for a candidate is to require the signatures of only 25 voters, the petition being accompanied by the candidate's consent. On this point the committee says:

Twenty-five electors are considered sufficient to place any one in competition for the nomination; for it is desirable that such competition should be free and open in the highest degree compatible with the public interests. No man should be prevented from seeking the support of his fellow citizens as an aspirant for a nomination because of any undue formalities or mechanical difficulties. On the contrary, the method should be very simple, recognizing fully that in a democracy every citizen should have ample opportunity to test the willingness of his fellows to support his honorable ambition as a candidate for nomination for an elective office. In a democracy free nomination should be encouraged, not hindered.

FIG. 5. TRACTION ENGINE TRAIN WITH 41-TON LOAD OF CEMENT MACHINERY.

The proposed law is very complete, the idea being to make the methods of nomination and selection as simple as possible. The report was accompanied by samples of the proposed ballots, which would be marked by a special stamp provided by the election officers, this taking the place of the general practice of marking with a lead pencil. Many of the provisions of the proposed law were criticised and objected to, and in view

Fig. 6. Mule Team and Truck for Hauling Steel Penstock Pipe.

of the time spent in the discussion, members were requested to continue the discussion by written communications. One of the principal features aimed at is to separate national for municipal politics, and to increase the importance of the primary election. Mr. L. E. Holden, of Cleveland, remarked that there was no special virtue in democratic sidewalks or republican sewers, except to aid the respective "grafters." But while the necessity of the separation of national from municipal politics were urged by many speakers, the president, Mr. C. J. Bonaparte, in his annual address, considered this to be impracticable and undesirable at the present time.

Partisanship in municipal affairs is a source of odious abuses, and the abatement of its evils should be a matter of grave and urgent concern to all in sympathy with the aims of the National Municipal League; but its elimination is, for the moment and as things are, neither practicable nor certainly and unreservedly to be desired. I believe that existing local organizations of the two national parties may be employed for certain purposes as useful agencies of municipal government, and even if it were possible to do away with them altogether the results of so doing might be disappointing and in certain cases disastrous.

Organizations formed of such politicians for such purposes can be agencies of good city government only against their will; and to compel them to become such agencies is, in my opinion, the immediate end of municipal reformers in America to-day. I say the immediate end, for I fully recognize that we may reasonably look forward to a time when the mass of our fellow-citizens shall have attained through long and sad experience a standard of enlightenment enabling them to elect a mayor or alderman for some other reason than his nomination as a democrat or a republican.

I believe the impression that politicians are generally acute and ingenious, though untrustworthy, is wholly groundless; the vast majority of them are men of the most moderate natural abilities and the most limited acquirements. I should be the last to maintain that "parties" composed of men such as these are ideal instruments of government, especially of municipal government. But, while we try to make them better, or even to make them step down and out, that better may fill their places, let us frankly recognize that, bad as they are, they are of some, and even of great utility, and that their removal from the sphere of city politics will leave a void which, if not aching, may yet be seriously inconvenient and imperatively demand to be filled. In truth, a self-governing community without definitely organized parties much re-

sembles a public meeting at which no one is prepared to offer a motion.

UNIFORM MUNICIPAL ACCOUNTING AND STATISTICS.

At the meeting on the morning of April 29, Mr. E. M. Hartwell, City Statistician of Boston, and chairman of the Committee on Uniform Municipal Accounting and Statistics, presented a report reviewing the development of this movement. Two papers on this subject were then presented. The first was by Dr. F. A. Cleveland, Professor of Finance in the University of the City of St. Louis, dealing particularly with the correct principles of accounting. The other was on uniform accounting in its relation to comparative municipal statistics, by Mr. L. G. Powers, Chief Statistician of the Bureau of Wealth, Debt and Taxation, U. S. Census Office. An abstract of the second of these is given in another column. A third paper, read by title, was on "The practical application of the schedules of the National Municipal League," by Mr. Harvey S. Chase, of Boston. This described in detail the application of the schedules in a number of cities.

In the discussion, a representative of the Chicago Bureau of Statistics, said that too much stress was laid upon the accounting and not enough upon the statistics. It is not sufficient to show how much has been received and expended, but the result of the expenditure, or the "service rendered" must be included. Reports showing, for instance, that more money has been expended for street cleaning in one year than in another, means very little, but if the reports show that the greater expenditure was, perhaps, for a smaller amount of street cleaning, the comparative service rendered is apparent. Where reports are made up annually, arbitrary or assumed statistics are frequently used. Only Boston and Chicago have, as yet, established bureaus of statistics. In Chicago, each department head receives daily reports, which are compiled for each month and transmitted to the Bureau of Statistics, which files and classifies them, and publishes groups of the monthly reports every quarter. Mr. Jackson, of the Chicago Federation of Labor, expressed the appreciation of the body in regard to the work of the League in promoting honest city government.

EDUCATION IN MUNICIPAL GOVERNMENT.

At the closing session in the afternoon, held at the Chicago University, papers were presented on the matter of teaching the principles of municipal government in the public schools and the higher institutions. Prof. L. S. Rowe (University of Pennsylvania) pointed out that instruction in municipal government has played too subordinate a part in university instruction to give the graduate the steadying influence of acquaintance with the mechanism of political life.

The test of educational efficiency is no longer the amount of knowledge absorbed, but rather the extent to which the student is prepared for service to his fellowmen and to the community, by increasing his industrial and civic efficiency. This new attitude places the teaching of civics and politics in a peculiarly prominent position and gives to the study of municipal government opportunities which it has never before enjoyed. The plan adopted by the University of Pennsylvania to bring students into direct contact with city affairs is the assignment to each student of a specific topic upon which he is required to report and which represents the results of personal investigation, has produced most gratifying results. The topic to which the work of inquiry is to be directed during the coming year is "The relation of the municipality to the street railway, gas and electric light services."

Mr. Geo. H. Martin, Secretary of the Massachusetts Board of Education, described the Ray and Gill systems of teaching municipal government in the schools by organizing the pupils into a "school city" with officers and a charter. Dr. Frederic L. Luqueer, School Principal, of Brooklyn, N. Y., showed how instruction in municipal government might be commenced in the elementary schools, and remarked that moral and civic instruction should go hand in hand.

We conclude our report of the proceedings with abstracts of two of the papers mentioned.

The Municipal Situation in Cambridge.*

In March, 1846, Cambridge became a city, but she did not adopt then and has not yet adopted the scientific businesslike and economical methods of work which characterize the private business of her own citizens, and which have been long in vogue in the cities of Great Britain and continental Europe. The salvation of our city has been the fact that she has always had among her citizens an unusually large number of able, public-spirited men, of knowledge, common sense and experience, who have given generously of their time, strength and money. That they have not been better represented in our city council is the fault of our municipal system. But that they have initiated improvements which our city has been glad to adopt, and they have served long and faithfully on committees and commissions which are not subject to the fickle changes of annual elections.

In 1888 our Manual Training School was founded by Mr. F. H. Rindge, who also paid all its running expenses up to 1900, when it was taken over by the city. For 11 years before they came under the care of our School Committee, free kindergartens were maintained by Mrs. Quincy Shaw and other Cambridge women. Vacation schools were conducted by private subscription before the city was ready to assume the burden of maintaining them. The Cambridge public library was also started through private munificence.

We are sometimes told that Cambridge is ruled by its aristocrats. If this be so, then the aristocrats of Cambridge are the public spirited men and women whose names will be found on the subscription lists and lists of workers of those movements to which I have referred, and of other similar movements that are still maintained by private support. The following are some of the private organizations supported by our citizens for the public good:

The Associated Charities, organized in 1881: In addition to its regular work it has exterminated the tramp nuisance; it has done away with the chattel mortgage evil which was making nearly 500 of our poor families pay from 50 to 120% a year on small loans; it has established nine stamp savings stations for children, which show a record of over 7,000 depositors; and it has aided in almost every other charitable work done in the city. The Prospect Union and the Social Union have supplied numerous courses of instruction, principally by Harvard students, at nominal rates to hundreds of working people each year. The East End Christian Union, with library, gymnasium, bathrooms, workshops, etc. The Avon Home for Destitute Children. The Cambridge Hospital, at an annual expense of over $20,000. The Holy Ghost Hospital, recently aided by the united efforts of many of the Protestant women of Cambridge. Perhaps the best illustration of co-operative work has been in the no-license movement which has resulted in a "No" vote for 18 years in succession.

Although the adoption of a City Charter in 1846 produced the usual result of the introduction of national politics into municipal affairs, we find that as early as 1854 there was a meeting of citizens who believed that party politics should not be a test of qualification for municipal offices. It was not until 1866, however, that *all* municipal nominations began to be made on a non-partisan basis; and this state of affairs continued until the fall campaign of 1901.

In 1889, after the nomination by caucuses of many unfit candidates for offices, there was a meeting in the rooms formerly occupied by the Public Library of those opposed to such candidates. A new list of candidates endorsed at this meeting was presented to the voters under the title of "The Library Hall Candidates." After a hard contest the objectionable candidates were defeated, and all but 4 of the 43 Library Hall candidates were elected. This led to the formation of the Library Hall Association. Its objects are shown by the following extract from its by-laws:

The purposes of this association shall be to secure the nomination and election of proper candidates for municipal offices; to procure the punishment of all persons who may be guilty of election frauds, maladministration of office, or misappropriation of public funds; to advocate and promote a public service based upon character and capability only; and to promote intelligent discussion of municipal affairs by the publication and distribution of reliable information in relation thereto.

During its first 11 years over 88% of its endorsements were ratified at the polls. Candidates for office who were members received no more consideration than those who were not, and in many cases the association endorsed candidates who were not members in preference to those who were. For several years Library Hall prepared and published a record of the acts of each member of the City Council, including attendance at meetings. It nipped in the bud the beginnings of corruption by calling public attention to the excessive number of car tickets used at the city's expense by some of the members of the City Council, and the use by members of the labor patronage of public service corporations. Members of the Executive Committee attended the meetings of the City Council and made reports on what they saw and heard.

The Library Hall Association became at length so large that its method of endorsing candidates was thought unsatisfactory. It was claimed that it was impossible at a single meeting of 300 or more members to discuss the merits and demerits of candidates thoroughly enough to ensure a vote for the best men. It therefore decided to change its method of work and to entrust the management of its business to a committee, and to change its name to the Good Government League of Cambridge. We are told by some of our good citizens that the American idea regards municipal offices as honors to be given first to one good man and then to another, and demands a city government in which three men must be hired to do the work of two. We are also told that it is nonsense to compare a city government (which has to do with moral and social as well as financial needs) with a money-making business corporation. These two ideas form the capital stock of the demoralized and demoralizing place-hunting and graft-seeking elements of our population.

The progressive idea has not yet found its way into our city charter. Our charter says that "All officers of the city not elected by the qualified voters shall be resident citizens of the city of Cambridge." What private institution or private business would ever hamper itself by such an un-American and suicidal requirement as this? In the same section power is given to the mayor, subject to the confirmation of the aldermen (elected at the same time with himself), to make appointments to salaried offices without any provision being made for ascertaining their fitness for the work which they are to perform. All of these charter provisions make for partisanship: (1) A mayor cannot appoint the best man if that man lives outside the city limits; (2) he is not required to apply any test of fitness; (3) he must appoint only those who can get the votes of aldermen, who naturally, and honestly perhaps, feel that they represent *constituencies*.

Our city charter by its division of power among the three branches of the city government deprives each branch of a proper sense of responsibility and puts stumbling blocks in the way of progress. Last year vacancies in the Overseers of the Poor were not filled for months because the Board of Aldermen and the Common Council could not decide whether to act conjointly or concurrently. This month a two-thirds vote of the Common Council for a much-needed water loan could not be obtained because some of the councilmen, though favoring the loan, would not vote for it without a guarantee that only Cambridge citizens should be employed by the Water Board. This obstruction has already cost the city thousands of dollars through a rise in the cost of material, and has made more imminent a feared water famine. Should the required guarantee be given, the added cost for labor alone would amount to $150,000, or from 30 to 40%. This illustrates the evils of a division of power and the ability of a misguided minority of a useless third branch of our city government, regardless of their oaths of office, to sacrifice the needs of all our citizens to the chance of getting a few positions for Cambridge citizens, which sound business policy might require the Water Board to give to others.

Can it be a matter of surprise that under our present charter many of our best and most experienced men, who are willing to put their shoulders to the wheel and to sink their hands deep down into their pockets in behalf of a specific municipal improvement, are unwilling to become candidates for the Common Council or Board of Aldermen?

Our present system, however, instead of being a source of despondency is a source of hope for it is so unsound, so unbusinesslike, so unscientific, so sure to produce unbearable inefficiency and high taxes that the public spirit of Cambridge, the Cambridge idea as it is sometimes called, will surely come to the rescue. The business principles in vogue in our private affairs and in the municipal affairs of foreign cities can and will be introduced into the management of the affairs of American cities. The annual report of the Good Government League, presented in February, 1904, contains the following suggestions for future work:

(1) The continuation of the work for the extension of the merit system for securing a better preparation for citizenship by our public schools.
(2) An early study and discussion of the question of lengthening the terms of office of the Mayor and members of the City Council.
(3) A study of the advisability of a single chambered City Council.
(4) A careful study of the relationship between the city and the public service corporations which use its streets, whether the use of our streets for private gain should not be paid for at the same rates that the city would have to pay for a similar use of private property; and whether the city should ever grant irrevocable rights to the use of its property.
(5) A study of our city charter with a view to finding out what changes should be made in it, that the management of our city affairs may become more economical, more businesslike and more efficient. Most of these suggestions have already been taken up.

Among other lines of work may be mentioned a public protest from the Executive Committee against the hold up of the water loan (to which I have referred), and the publication of impartial information about candidates for office just previous to the last city election. More stress has been laid upon measures than upon men because an improvement in our system is a permanent change for the better and tends to produce good men, while a contest over men alone has to be fought over again every year.

The Municipal Program.*

At the Louisville convention of this League, seven years ago, Mr. Horace E. Deming, of New York, presented the following resolution:

Resolved, That the Executive Committee appoint a com-

*By Mr. H. N. Wheeler, President of the Good Government League of Cambridge, Mass.

*By Dr. Delos F. Wilcox, Secretary of the Civic Club of Grand Rapids, Mich.

mittee of ten to investigate and report on the feasibility of a Municipal Program, which shall embody the essential principles that must underlie successful municipal government and which shall also set forth a working plan or system, consistent with American political institutions and adapted to American industrial and political conditions for putting such principles into practical operation; and said committee, if it find such a Municipal Program to be feasible, is instructed to report the same, with its reasons therefor, to the League for consideration.

The Municipal Program is an attempt to crystallize and formulate the best American theory as to the right organization of municipal government. It is not calculated to ensure good administration, but to give an opportunity for it. Its principal purpose is to free the popular will and to break down the barriers that now hinder us from the realization of municipal government, of, for and by the people. A brief review of the principles of municipal reform as embodied in the Program and illustrated in the recent experiences and present necessities of American cities may be of value. These principles are chiefly the following:

(1) That every city or other local community should have the right of self-government in its local affairs without the interference of outside governmental or party machinery.
(2) That the city's public property in land, with especial reference to franchise rights, should be so safeguarded as to be preserved unimpaired for the use of all the people in this and future generations.
(3) That all barriers should be removed which prevent the popular will from freely and effectively expressing itself as the public will.
(4) That municipal administration should be conducted in the main by a class of public servants who by reason of experience and special training are particularly fitted for their official duties.
(5) That official responsibility should be so placed, through simplification of governmental machinery and full publicity of accounts, that the people may hold their public servants to the execution of the public will with the least possible delay and uncertainty.

(1) HOME RULE.—The Municipal Program confers upon all cities by constitutional guarantee a general grant of governmental powers, including the same powers of taxation as are possessed by the state and the power "to perform and render all public services" subject only to specific limitations by state law. In other words, the rule that a municipal corporation is a body with enumerated powers to be strictly construed is reversed, and any function not specifically forbidden by state law may be undertaken by a city.

The Program requires every state legislature to enact a general municipal corporations law, and offers a draft of such a law. This general act is to be applicable to all the cities of the state, and be operative in such cities as adopt it by popular vote. With a general grant of powers there is no need for special charters from the state legislature to cities of various sizes and locations. The Program puts a direct and powerful check upon state interference, while not absolutely prohibiting it under all circumstances.

The Program reserves to every city of more than 25,000 population the right to frame and adopt its own charter. This plan is in practical operation in varying degrees of completeness in five commonwealths. These commonwealths contain eight cities with over 100,000 population each, and eight others with more than 25,000. This is often misunderstood as conferring upon aldermen the right to make and amend charters. As a matter of fact, the scheme leaves to the people of the city the right by means of a constituent convention to frame their own charter and put such limitations upon the powers of the city council as they see fit.

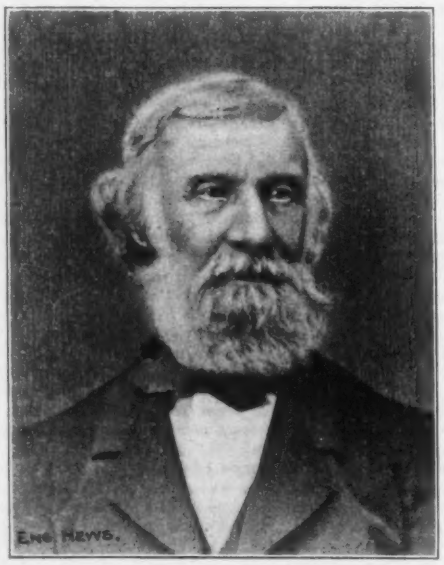
As a final guarantee of home rule, the Municipal Program strikes a body blow at the interference of political parties in city elections. It provides that municipal shall be separate from state and national elections and that all nominations for municipal offices shall be made by petition and the names of all candidates printed together on the ballot. A few important cities now nominate their officials by direct vote of the people, and free nominations by petition are an essential feature of a home rule program.

(2) FRANCHISE RIGHTS.—The second principle of the Municipal Program is that a city's rights in the streets, parks, waterways and other public places should be inalienable so long as these places are needed for public use. They can be alienated under no circumstances except by a four-fifths vote of all the members of the council, approved by the mayor. Franchise grants are limited to 21 years, in order that the rights of a future generation to the full and free use of the streets may never again be taken away by the corrupt or heedless representatives of this generation. In order that the city may in reality retain the full use of its property, every city is permitted to exercise the option of operating its own franchise if it sees fit. Indeed, the city is exempted from all limitations upon its indebtedness for these purposes, provided only that it operates its public utilities so that they are self-sustaining. To further guarantee the city's rights, every franchise holder is compelled to keep detailed books of account open to the inspection of the city and make quarterly financial reports to the city comptroller.

(3) DIRECT POPULAR RESPONSIBILITY.—The third principle of the Municipal Program is that the will of the people shall prevail. To this end the initiative in the adoption of amendment of city charters is given to the people by means of petitions signed by a small percentage of the voters. This provision alone would open the way for full popular control of local government. But the Program goes further and provides specifically that on popular petition or otherwise any city may establish a system of direct legislation applicable to all city matters.

(4) MUNICIPAL ADMINISTRATION.—The fourth principle of the Program is that city officials need to know their business. It is gradually dawning upon the American mind that special knowledge is required to run the machinery of city government. It is not enough for a man to be a "good fellow" or to know how to read and write or to be successful in business even, to make a good city official. The complex machinery of a city can be run only by those who know how to do that particular thing. The city engineer's force, the employees of the board of health, the park superintendent, the water-works employees, the auditing clerks, and practically the whole body of municipal officials need special knowledge and long experience to give the city the benefit of good service. And so the Program provides that "all appointments and promotions in the subordinate administrative service of the city, including laborers, shall be made solely according to fitness, which shall be ascertained, so far as practicable, by examinations that, so far as practicable, shall be open competitive examinations," and that "all persons in the administrative service of the city, except the mayor, shall hold their offices without fixed terms." There is elaborate provision for the regulation of the civil service and every effort is made to avoid the pitfalls which are found in civil service regulations not adequately worked out to fit practical conditions.

(5) DEFINITE OFFICIAL RESPONSIBILITY.—The fifth principle of the Municipal Program is concentration



Yours very truly
Chas. S. Storrow

of official responsibility. The mayor and council are to be the only officials elected by the people, the one being made responsible for the whole administrative service outside of the finance department, and the other being given all legislative powers not retained by the people themselves. The mayor is to appoint and remove all heads of departments at pleasure, except the comptroller. All subordinate administrative officials are appointed by him, subject to civil service rules, and may be removed by him for reasons stated in writing, but not based on religious or political considerations. The financial department of the city is to be in charge of the comptroller, who is to be elected by the council and be responsible to that body.

Such are the main features of the Municipal Program adopted by this League five years ago. It has nowhere been enacted into law as a whole, but its influence has been felt practically everywhere that charters have been framed, constitutions revised or municipal reform agitated. It was published in full in Honolulu for the benefit of the Hawaiian legislature. It was used by the Havana Charter Commission and, I believe, by the Porto Rican and Philippine Commissions. It has left marked traces in the new constitutions of Virginia and Alabama and has formed the basis for a sweeping amendment to the Colorado constitution. The charter commission of Portland, Oregon, used it. The charter revision commission of New York city adopted some of its provisions. The Duluth and St. Paul charters are in line with it in important respects. It has formed the basis of agitation for charter reform in Wisconsin, Michigan, Delaware and doubtless many other states.

CHARLES STORER STORROW.

Eleven years ago, in prefacing an account of the life work of the eminent engineer whose portrait is here presented, the author of the article (the late A. M. Wellington) wrote:

The world moves so fast nowadays that after a man once retires from active practice, as Mr. Storrow did many years ago, he is apt to be forgotten even in his own profession. Hence, to many of the present generation of engineers even the name which heads this article may be entirely unfamiliar.

At the time the above was written, Mr. Storrow had reached the advanced age of 84 years, and 14 years had passed since he had been engaged in active practice. The news now reaches us of his death on Saturday, April 30, having passed his 95th birthday; and it may be truly said that the Nestor of the American civil engineering profession has passed away, although he had so long outlived all his contemporaries and had spent so many years in quiet retirement that to-day, even more than eleven years ago, the present generation of engineers knows little of him.

The article referred to above was published in our issue of Feb. 16, 1893, on the occasion of the election of Mr. Storrow to Honorary Membership in the American Society of Civil Engineers, and the accompanying portrait is reproduced from one which accompanied that article. These eleven years have seen such great changes in the profession and in the readers of Engineering News that we deem it well worth while to repeat again the story of Mr. Storrow's life and professional career. It forms a most important chapter of that history of American engineering which is some day, we hope, to be compiled and published.

Mr. Storrow's father, Thomas Wentworth Storrow, was one of the old time merchants of Boston and was an intimate friend of the eminent Loammi Baldwin, from which resulted, no doubt, the decision of the son to follow, the then practically unknown profession of engineering. Mr. Storrow was born on March 25, 1809, and he graduated from Harvard in the class of 1829, among his classmates being Oliver Wendell Holmes, James Freeman Clarke (whose younger brother, the late Thomas Curtis Clarke, won a high place among American engineers) and Benjamin Pierce, the famous mathematician. As illustrating how long Mr. Storrow outlived his contemporaries it may be remarked that eleven years ago Oliver Wendell Holmes was the only other surviving member of the class, and that for some time Mr. Storrow has been next to the oldest surviving graduate of Harvard.

In 1829, when Mr. Storrow finished his studies at Harvard, there was practically no such thing as engineering education in the United States. Men became mechanical engineers by working with the "millwrights" of the day or they became civil engineers by actual work with the few canal engineers of that time, for canal building was about the only field of employment then requiring the services of the civil engineer.

Mr. Storrow, however, set out to obtain an engineering education and began by diligent reading in the library of Loammi Baldwin during his senior year in college and during the following six months. In December, 1829, he went to France and became a student at Ecole des Ponts et Chaussees, and also attended lectures at the Ecole Polytechnique. These studies continued until the spring of 1832. During his stay abroad Mr. Storrow visited England to see the work of railway construction then in progress on the Liverpool & Manchester Ry., which George Stephenson was then building, and it is even stated that he worked for a short time on this road. Thus within the period of active life of one man, the entire railway development of the world has taken place.

Returning to America, Mr. Storrow was at once employed under Loammi Baldwin as an Assistant Engineer on the construction of the Boston & Lowell, the first steam railway of New England. On its completion he became its first general manager and continued in that position for 12 years.

It is stated that Mr. Storrow, by virtue of his

brief experience on the Liverpool & Manchester Ry., was the only person connected with the Boston & Lowell Ry. during its construction who had ever actually seen a locomotive running on iron rails.

Mr. Storrow had, however, a particular fondness for hydraulics. Soon after completing his studies in France he published a treatise on this branch of engineering, which was the first treatise on hydraulics in the English language. It made available for the first time to English-speaking engineers the work of the French writers, Prony, Belanger and others. While general manager of the Boston & Lowell he carried out for the Lowell Locks & Canals Co. a series of measurements on the water used by the Lowell Mills, and later advised the proprietors of that company to employ the young Jas. B. Francis to continue that work.

It is hardly necessary, perhaps, to recall here that Mr. Francis afterward became the most eminent of American hydraulic engineers, and that the record of his experiments at Lowell forms a classic in engineering literature. His death occurred a dozen years ago.

In 1844 the Essex Company was incorporated by merchants of Boston for the purpose of developing water power at rapids on the Merrimac river, ten miles below Lowell. Large tracts of farm land were purchased and a new manufacturing city was founded and named Lawrence, after the eminent Abbott Lawrence who was at the head of the company and was at that time perhaps the most prominent business man in New England.

Mr. Storrow was selected as the engineer of this enterprise, and became himself a stockholder in it. In its development this power stands alone of all the early American water powers as showing a clear appreciation of the end in the beginning. The sluiceways and canal section were computed so accurately before the work was begun that they have remained well suited to the demands upon them to the present day. The magnificent gravity dam across the Merrimac river 33 ft. in height with its overfall 900 ft. in length, personally designed by Mr. Storrow, has stood for the 56 years since its completion without costing one dollar for repairs and is to-day a model structure. Cement tests and the use of cement concrete for filling the voids in rubble masonry as used in this dam antedated the general introduction of similar methods by many years.

Mr. Storrow also laid out the streets of the new city, was financial manager of the Essex Co. and had a large voice in the building and management of some of the great mills which were erected to utilize the power. In recognition of his services as founder of the city, Mr. Storrow was made its first mayor.

Practically the whole of the remaining years of his active life were devoted to this enterprise until his final retirement from business a quarter of a century ago, on attaining the age of 70 years.

In 1862 Mr. Storrow was commissioned by Governor Andrew of Massachusetts to visit Europe and study the use of compressed air on the Mont Cenis and other tunnels, with a view to furthering work on the then long delayed Hoosac tunnel. He was also a year earlier a member of a State Commission appointed to report on the improvement of the Sudbury and Concord rivers, and was one of the earliest members of the Boston Park Commission.

It is probably true, as we have noted, that Mr. Storrow was the first American engineer educated in an engineering school. He was also among the first to take an active interest in the work of engineering education. It was Mr. Storrow's account of the engineering schools of France to his business associate, Hon. Abbott Lawrence, that led to the founding in 1846 of the Lawrence Scientific School of Harvard University. Mr. Storrow was urged to become the head of this institution at its foundation, but he preferred the more active life in connection with the great works of the Essex Co.

Mr. Storrow made his home at Lawrence during the early years of the city and later changed his residence to Boston while continuing as treasurer and general manager of the company until about 25 years ago, when at the age of 70, he retired from active business.

His afternoon of life has been exceptionally serene, cheered by the companionship of his devoted daughter, Mrs. Lydia J. Dale, and saddened only by the loss of his wife and later by that of his son, the eminent patent lawyer, Jas. J. Storrow. His health and bodily vigor continued remarkably good until the past few years and his remarkable intellectual qualities were keen to the last.

Those who had the pleasure of personal acquaintance with Mr. Storrow pay high tribute to his fine personality and the charm of his manner. Surely it is worthy of particular note that this distinguished man, entitled to rank as one of the founders of American engineering, had such personal qualities as to command this tribute from a fellow engineer at the close of a personal letter informing us of Mr. Storrow's death:

"Mr. Storrow came nearer the ideal of the perfect gentleman than any man I have ever known."

A GRAVE DANGER to the City of New York is presented by a bill which passed the last Legislature, and is now awaiting the approval of Gov. Odell, which we sincerely hope may be withheld. The bill would prevent New York City from taking for its water supply the streams lying in Dutchess county to the north of the Croton watershed. The appropriation of these streams was recommended by the recent Commission on Additional Water Supply, in their report published in our issue of Oct. 1, 1903; and these streams are of particular importance, since they are the only sources of additional supply available on the east side of the Hudson, and the only sources from which water can be brought quickly enough to save the city of New York from danger of a serious water famine. To develop and bring water from the much more distant gathering grounds to the west of the Hudson will require at best several years' longer time, and New York cannot wait so long for more water without grave danger of water shortage in a dry season.

The only reason assigned in defence of the bill is that the taking of water from these streams might cause the removal of some manufacturing industries which now use water-power on these streams. While the damage to the water-power would, of course, be compensated by the city, it is claimed that the removal of factory operatives, etc., would cause a general injury to real estate.

So far as there may be any basis for such a claim, it could be wholly met by provision for furnishing "compensation water" to streams, as is done in England. The present bill, to protect a few owners of farms and houses from possible loss as yet undemonstrated, would inflict a grave and irreparable injury on a city of four millions by placing it in imminent danger of a water famine. It is to be hoped that the strong representations which have been made to Gov. Odell may induce him to withhold his approval from the bill.

RIVER GAGING IN NEW ENGLAND is being actively carried on by the U. S. Geological Survey. The work is under the direction of District Hydrographer N. C. Grover, with office at Bangor, Me. Assisting Mr. Grover are Messrs. S. Clapp, H. K. Barrows and F. E. Pressey.

Systematic measurements are now being carried on at the following stations in New England:

Stream.	Station.
MAINE.	
Androscoggin,	Dixfield.
Aroostook,	Ft. Fairfield.
Carrabassett,	North Anson.
Dead,	The Forks.
Fish,	Wallagrass.
Kennebec,	North Anson.
Kennebec,	The Forks.
Machias,	Whitneyville.
Mattawamkeag,	Mattawamkeag.
Messalouskee,	Waterville.
Moose,	Rockwood.
Penobscot,	Montague.
East Branch of Penobscot,	Grindstone.
Piscataquis,	Low's Bridge, Foxcroft.
Roach,	Roach River.
Sandy,	Starks.
St. Croix,	Sprague's Falls, Baring.
NEW HAMPSHIRE.	
Ammonoosuc,	Bretton Woods.
Androscoggin,	Shelburne,
Ashuelot,	Winchester.
Connecticut,	Orford.
Contoocook,	West Hopkinton.
Israel, above So. Branch,	Jefferson Highlands.
Israel, below So. Branch,	Jefferson Highlands.
Little,	Twin Mt.
Merrimac,	Franklin Junction.
Pemigewasset,	Plymouth,
Saco,	Center Conway.
Zealand,	Twin Mt.
VERMONT.	
Otter Creek,	Middleburg.
White,	Sharon.
Winooski,	Richmond.
MASSACHUSETTS.	
Connecticut,	Sunderland.
Deerfield,	Deerfield.

THE AQUEDUCT COMMISSION OF NEW YORK has prepared an interesting exhibit for the World's Fair at St. Louis. The exhibits will include a model of the new Croton dam and an old model of the Croton dam of 1841; specimens of the old wooden water pipe, of 1799, instruments used in the construction of the new aqueduct, and a series of 130 enlarged photographs showing the stages of construction on the new work. Accompanying the exhibit will be a pamphlet giving a brief history of the water supply of New York, and a description of the various separate exhibits.

THE CALUMET DRAINAGE CANAL, from the Calumet River to the Chicago Drainage Canal, is to be built on what is termed the Sag route. This route has been adopted by the engineering committee of the Chicago Sanitary District, and the District will purchase a strip of land 1,000 ft. wide along this route. The canal will be 70 ft. wide in earth and 90 ft. in rock. Detail plans will now be prepared, and bids asked for the work, which is estimated to cost $12,000,000, and to occupy three years. Mr. Isham Randolph is Chief Engineer of the Sanitary District, and the Calumet Canal will be built under his direction.

PLANS FOR ADDITIONAL SUBWAYS have been submitted to the Board of Rapid Transit Commissioners of New York City by the Committee on Plan and Scope. The proposed new work may be roughly divided into an East Side line from the Bronx to the Battery, a West Side line from the Battery to 42d St., a Brooklyn extension from the present line at Canal St. across the East River to Flatbush Ave. and thence south to Fort Hamilton, and a number of connecting spurs and branches. In reporting these new lines the committee recommends that bids should be invited for building them in several sections so as to ensure competition; that stringent requirements should be made for maintaining traffic and avoiding extensive disturbances of the street surfaces; that the entrances to stations should be located on private property, and that efforts be made to secure the construction of pipe galleries in connection with the subway work. The crossing of the East River by the Brooklyn extension is to be made over the Manhattan Bridge, now under construction. The exact routes of the new lines may be traced by those interested from the following schedule given in the report:

The proposed new subway route begins with a connection with the present subway at 149th St., runs along Morris Ave. to Third Ave., thence under private property, intervening streets, and the Harlem River to Lexington Ave., to Irving Place, to 15th St., under Union Square to Broadway, to Chambers St., to Park Row, and private property to William St., to South William St., to Broad St., to South St., to Battery Park, to Greenwich St., to West Broadway, Washington Square, and under private property to Greenwich Ave., to Seventh Ave., to 43d St., to the subway. A spur from Lexington Ave. at 45th St. passes under private property, intervening streets, and the yard of the Harlem R. R. to the subway under Park Ave., south of 40th St. Another spur under 34th St. connects Lexington Ave. and Seventh Ave. lines. The Brooklyn extension starts at Fort Hamilton, runs through Fourth Ave. to Flatbush Ave., the new street to be constructed to the Manhattan bridge, over the bridge to Manhattan, to Canal St., to Centre St.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the St. Louis, Iron Mountain & Southern Ry., near Kimmswick, Mo., on April 30. A passenger train running to St. Louis as a special for the opening of the Louisiana Purchase Exposition, and running at high speed to make up time, was derailed at a switch and completely wrecked. Some ten persons were killed.

ACCIDENTS TO PERSONS IN CHICAGO in 1903, compiled from the police records, amounted to a total of 10,707. The largest number of one kind were those classed as "run over or struck by street car," 457, but accidents to persons struck by locomotives and trains were almost as numerous, being 446. Collisions between street cars and wagons caused 442 injuries, and 331 persons were injured in alighting from street cars. Of the railway accidents, 33 occurred in coupling cars, and 48 occurred on the elevated railways. The general summary, as compiled from the police records by the Chicago Civic Federation, is as follows:

Street railway accidents	2,035
Steam and elevated roads	914
Caused by teams and vehicles	898
Caused by falling	1,275
Caused by falling objects	369
Caused by explosions	117
From various causes	1,174
From personal violence	1,156
Other causes reported by police	2,789
Total accidents reported by police	10,707

THE HEADINGS OF THE SIMPLON TUNNEL by the end of March, 1904, reached a total length of 60,218 ft., of which 33,381 ft. is the length of the north heading, and 26,837 the length of the south heading. The average daily advance during the month of March of the south heading was 15.6 ft. In the north heading work was interrupted for a large part of the month for the construction of a bulkhead a short distance back of the face. The average advance during the working period was 9.8 ft. per day.

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see pages 26-27. New copy for standing advertisements should be received ten days in advance of publication; new advertisements, Monday morning. The pages containing "Want" advertisements are held open until Tuesday, and those with "Proposal" and "For Sale" advertisements until Wednesday at 11 a. m.

We risk little in saying that the elaborate article in this issue on the effects of compressed air on the human system and the cause of the disease known as "the bends" is the most valuable contribution ever made to the literature of this subject. The authors of this paper, as a result of most exhaustive investigations, have proved that the cause of the bends is nothing but the escape of air or gas bubbles from the blood in the circulatory system when the air pressure is reduced. The veins of a man who is attacked with the bends in passing out of an air lock are in a condition comparable to that of a soda water bottle when the cork is removed. Bubbles of air or gas, which have been absorbed by the blood while he was under pressure, are formed all through the blood and tend to derange the circulatory system in a variety of ways. One way which appeals particularly to engineers, because of its mechanical nature, is the effect on the heart. As everybody knows, the heart is simply a pump which Nature has provided to force the blood through the circulatory channels. If air bubbles are formed all through the veins and arteries of a man coming out of compressed air, these bubbles will tend to coalesce and increase in size as they flow along. Some of them may collect at high points, as they do in an engineer's pipe line, and remain there until the whole mass is forced at a gulp toward the heart. The pumps which the engineer builds for moving water work very badly for pumping air, and Nature's pump likewise works badly when air instead of blood enters it. There appears to be no doubt that this is one explanation of the sudden deaths which at times occur on leaving an air lock.

And now that the cause of the disease is definitely known, the method of its prevention is equally plain. It is in fact what has been understood by experts for years to be the proper method of preventing the bends, viz.: making the working shift short and come out very slowly through the air lock.

If the shift is short, the blood does not have time to become charged with the full quantity of gas which it would absorb under the high pressure. If the passage through the air lock is slow the gas given off by the blood will be gradually eliminated through the lungs without serious interference with the action of the heart or the capillaries.

We will not take space further to trace the action of the compressed air on the system, for the important point, deserving of chief attention, is that prevention of the bends, now that the cause is known, is a duty incumbent on every engineer and contractor who works men in compressed air. Common humanity as well as the common law dictate that employees shall not be exposed to any danger which due diligence, the use of reasonable foresight and the adoption of well-known methods can prevent. Every air lock should have an adjustable locked escape valve, which should prevent the men from passing through the lock at any time faster than safety will permit. This should be adjusted from time to time to suit the depth of excavation and the pressure of the air. As soon as any symptoms of the bends are detected, it is to be taken as an indication that the shifts are too long, or the time of passage through the air locks too short, and the proper amendments should be immediately made.

If this is not done and if a number of men die or are crippled by the bends, there is good reason to suppose that the contractor could be mulcted in heavy damages, just as if the men had suffered from some accident due to defective material which he had furnished. It is doubtful if this responsibility could be evaded even by an employment contract absolving the employer from liability for damages due to diseases caused by the compressed air. The law does not sanction contracts by which a man forfeits his right to the reasonable protection of life and limb. It has been held that contracts which tended to make an employer careless of the safety of those whom he employs were against public policy, and therefore void.

We do not assume, of course, to express any legal opinion in the case; but it seems at least clear that it will pay a contractor from mercenary motives as well as from motives of humanity to safeguard to the fullest possible extent his employees working in compressed air, and he can now do this with intelligence and certainty.

There can be little doubt that the Spanish war gave a decided impetus to the adoption of high speed in battleships. For weeks during that war it was supposed that the fast armored cruisers of the Spanish Navy were capable of doing a vast amount of damage to American coastwise traffic and coast towns, and that they could by their superior armor and armament whip any American cruiser fast enough to catch them, and run away from any American battleship powerful enough to fight them. Of course, it was later discovered that the superiority of the Spanish vessels in speed and offensive powers existed only on paper, and that they were wholly unfit for active service; but the lesson had been impressed on the world that battleships should be made fast enough to catch cruisers.

The hostilities between Japan and Russia appear to be swinging the pendulum in another direction, and may even bring about that worldwide cessation in the construction of battleships which the advocates of the submarine boat have long been prophesying. In the U. S. Senate on April 25 a discussion took place in which the opinion was freely expressed that the huge battleship may soon be rendered obsolete by the development of the submarine boat and the torpedo.

Of course Senators are not naval experts; and the naval officers whose opinions generally rule in the matter are conservative and rightly so with reference to changes in the accepted principles of naval construction. Nevertheless it must be freely recognized that the course of future naval construction is likely to be greatly influenced by the actions between Russia and Japan; and thus far the mine and the torpedo have shown an importance much greater than that usually assigned to them by naval experts. On the other hand, the importance of the possession of sea power and of a large preponderance of naval strength has likewise been strongly impressed upon the world, and would tend to influence even larger expenditures upon naval development than have yet been made. The doubtful feature in the problem is the submarine boat, which has had such a rapid development during the past half dozen years. Its capabilities of destruction are not likely to be shown in the present war; but its rapid improvement makes it a factor to be considered by every nation before embarking on any large naval programme. This much is certainly clear, that the underwater portions of all these great steel vessels, costing from $3,000,000 to $7,000,000 apiece, are exceedingly vulnerable to any high explosive, and that the progress of invention is at the time improving methods of attack by the mine, the torpedo and the submarine boat. The chances seem strong that the opinions expressed in the Senate may prove to be correct, and that a few years hence may see the present battleships as obsolete as are now the old monitors.

Is the modern test for hydraulic cements a reliable criterion of the suitability of any particular cement for engineering construction? There is in the minds of a considerable number of engineers some doubt upon this question. The standard cement specifications of the Engineer Corps, U. S. A., require that a cement shall have had three years' successful use under similar circumstances before it shall be considered available for any Government work. In recent Canadian Government specifications for public work it is stated that any cement not of a brand known by prior use on extensive works may be declined without testing. Recently a number of engineers have in their private work adopted a similar practice of limiting the brands of cement which it was permissible to use to those that could show continuous and successful use for a period of five years prior to the date of construction. In some instances the engineer has specifically limited the choice to one or a few named brands. Were this practice of restriction to cease with Government work or with the work of an engineer now and then, there would be little occasion for remark, but there is a tendency for it to grow and ultimately, perhaps, to become through imitation a standard requirement for all cement work. This tendency deserves consideration.

The right of an engineer, if he chooses, to restrict himself to the use of one or a limited number of brands of cement is unquestionable. In fact, it may be highly desirable and in all respects good engineering to impose these or even stricter limitations in certain instances. The important question is, whether it is the part of fairness and good engineering to extend this policy to general practice. It has not been the policy under which the cement industry of America has grown in scarcely a decade to dimensions that establish the United States as the leading cement manufacturing country of the world. The policy that has conduced to this growth has been one of wide open competition in meeting test requirements. So long as a cement met the engineer's tests it was a good cement, its name and pedigree were matters of secondary importance. Practice abroad has been no different. In German, French and English practice every cement that will pass the standard tests is available for Government work. What justification has the engineer for taking a different attitude than that assumed in the past and that under which the hydraulic cement industry has grown up?

If we are to accept the doctrine that no cement should be used that cannot show a record of several years previous successful use, it means nothing else than that engineers discredit the results of the tests for cement that they have been at such pains and expense to establish and standardize. This is not merely a hypothetical assumption. Only recently a staunch advocate for the practice of demanding of cement a record of service justified his position by pointing out that there are a great many uncertainties as yet in the testing of cement, and a man skilled in its manipulation can produce almost any results by tests that he may desire. There is a measure of truth in this statement, but even if we admit its entire truth it possesses no great force. It is the engineer himself who makes the test, either personally or through a personal employee or agent, and it is then his own fault if results are obtained which are false and unreliable. In fact, he can easily go farther, if false results are so readily obtained, and turn the fraud to his own advantage.

In view of these facts, the engineer seems hardly justified in refusing to stand by test results unless he believes that modern methods of cement testing are essentially unreliable. We doubt very much whether engineers are prepared to admit this. It is reasonably certain that no engineer would accept a cement without test for an important structure on the mere strength of its brand name, however reputable that might be. If the methods of testing cement that are now practiced are sufficiently reliable to warrant engineers in declining a cement backed by a reputation of years, why should they not be sufficiently reliable to warrant engineers in accepting a cement against which there is no accusation except that it has not been previously used for three or five years? There can be little fairness, however we contrive, in insisting that no cement shall be used which does not pass tests unless we grant that a cement which does pass tests may be accepted. If engineers accept any other principle it simply means that they judge a cement on some other basis than its intrinsic merits.

We quoted not long ago a recent estimate made by Dr. Victor C. Vaughan of the University of Michigan of the annual loss to the nation from the prevalence of typhoid fever. A somewhat similar estimate has been made by Dr. Lewis, of the New York State Board of Health. Taking five of the preventable diseases, he finds the total mortality from them in New York State during the year 1903. He then estimates the value of the average human life at $5,000, and in this way computes that the total loss to the people of the State of New York, by the deaths from these five preventable diseases in 1903, amounted to $94,900,000. Of course it may be said that this estimate is excessive in view of the fact that many of these deaths occur among old people, whose expectation of life is comparatively short, anyway; but, on the other hand, this estimate does not take into account the many million dollars spent on physicians, medicine and nursing for those who are ill and recover as well as those who die. Dr. Lewis makes this estimate an argument for more liberal State appropriations to carry on health protective work, and his argument holds good for other states than New York.

Some months ago we printed a valuable series of contributions on the relative resistance of wrought iron and steel pipe to corrosion, in which a large number of engineers reported as a result of their experience that wrought iron pipe corroded much less rapidly than steel. In a recent number of the "Proceedings of the Engineers' Society of Western Pennsylvania," we find a paper by Mr. Victor Beutner on "The Manufacture of Welded Pipe," and the following quotation regarding the use of steel pipe is of especial interest:

> To-day by far the greater portion of welded pipe is made of steel, and even the difficulties which presented themselves in threading the soft basic open hearth steel are being rapidly overcome. A representative analysis of the steel used for skelp ought to show about: Carbon, 0.05; manganese, 0.36; phosphorus, 0.1; sulphur, 0.05; silicon, 0.02.
>
> These properties, however, might be materially modified by individual experience or preference.
>
> Generally speaking, steel presents less difficulties in manufacturing than wrought iron, being much "cleaner" to handle and furnishing a more uniform and reliable product. The only exception is the well-known power of resistance of pure wrought iron to the influence of rain or other atmospheric moisture and to the corrosion by the soil, if exposed to either, without protection. In such case the wrought-iron pipe will outlast the steel pipe nearly three times.

It is to be noted that this is the testimony of an engineer of long experience in pipe manufacture and presumably familiar with the reports of customers and purchasers regarding experience in the use of pipe.

Certainly, if this is a correct statement of the relative resistance of wrought iron and steel to corrosion, there are many users of pipe who could well afford to pay a much higher price to obtain wrought iron pipe instead of steel.

Even if this be an overestimate, and if wrought iron is only a little more durable than steel, say, for example, that a wrought iron pipe will have a life 50 per cent. longer than a steel pipe, it will still, in many cases, be very well worth while to pay a higher price for wrought iron pipe. It must be remembered that the cost of the pipe itself is often only a small part of its cost in the place where it is to be used. In wrought iron gas or water pipes, for example, the cost of laying may be much more than the cost of the pipe, and if one pipe will last twice as long as another, it is worth to the purchaser much more than twice as much.

There is, in fact, an urgent demand for some kind of pipe which can show a greater resistance to corrosion and a longer life than the commercial pipes now available. One notable example of this is brought before us by a letter just received from Mr. Alex. B. Moncrieff, Engineer-in-Chief of South Australia, from which we quote as follows:

> Recent experience with some deep well bores in this state, lined with the very best wrought iron casing, shows that after a number of years even this casing seriously deteriorates and is liable to rust through, to the great risk of losing the well. In some of the bores the water flows with considerable velocity and the temperature ranges as high as 204°. Can you, or some of your readers, kindly let me know whether successful experiments have been made in the United States for overcoming the difficulty referred to, viz., the deterioration of the casing by the action of mineralized water discharged rapidly and at a high temperature? With bores which have reached a depth of 4,000 to 5,000 ft., this is an important point.

It is to be noted that this pipe is stated to be wrought iron and not steel. What the mineral water is, is not stated, but it is likely that common salt is a chief ingredient, and the rapid corrosion of either steel or iron under such circumstances is, of course, to be expected. Brass pipes would doubtless be too expensive for consideration, even if they would stand driving, which is more than doubtful. The only resource, therefore, would appear to be the use of some form of protecting coating, such as heavy galvanizing, tinning, or perhaps coating with a baked enamel japan, such as has been used on large steel water mains and more recently on the floor members of the Williamsburg suspension bridge.

We shall be glad to hear from any of our readers who can give further information bearing on the question raised by Mr. Moncrieff.

THE DEMAND FOR ENGINEERS OF BUSINESS ABILITY.

One of the Assistant Engineers of Construction on the Pennsylvania Railroad recently remarked to one of the editors of this journal:

> You doubtless want to know what the most interesting feature of my work is. Well, to me the most interesting fact is that we can't get enough engineers to handle the work in hand.

From many sources similar complaints are heard about the "scarcity of engineers." When we examine the advertisements offering positions, or when we read the statements of employers frequently published in daily papers, we see that the dearth is not so much one of engineers in general as lack of a particular kind of engineers—engineers of business ability.

It is true that the young engineer on graduation has for the past four years found numerous opportunities open to him; perhaps more than ever before. Nevertheless, he soon learns that positions where rapid advancement is possible are not common. Coming fresh from his studies, the graduate also finds it hard to decide what are the really "promising positions," the ones in which there actually is something more than mere promise. Perhaps a few suggestions may be opportune.

To begin with, there is no lack of young men who can handle surveying instruments in a more or less skillful manner, and no lack of young men capable of making mathematical computations. These subjects are usually well taught in our engineering schools, and as they make "nice, clean work," work requiring skill, and work directly in line with previous training, we need not be surprised to find no great dearth of men for such positions. But for that very reason, and for other reasons, we incline to the opinion that the ambitious and far-sighted young engineer will seek work that is not so much to his taste at first, but which may be much more to his taste in the end. We refer to structural or manufacturing work, where business ability, coupled with an engineering training, will mean financial success.

Having decided upon a commercial engineering career, the young man should not hesitate to accept any wages or any work, however menial, in order to gain a foothold. The very fact that the work is "dirty work" and that the pay is low should encourage rather than discourage, for in just such work are the ambitious man's opportunities greatest if he seeks to attract especial attention to his ability. Several years ago when engineering positions were hard to get, a young engineer took a job shoveling concrete; certainly not very attractive work and apparently offering little chance for advancement. He stuck bravely to his shovel, however, and noting that the output of the gang was about two cubic yards each per day, he determined to find out why it was not three. He had read somewhere that three cubic yards of concrete is a fair day's work for a man. In this particular case the concrete was used to line a reservoir, and was mixed near the foot of the sloping sides, carried several steps in shovels and cast up to men who spread it upon the slope. Naturally, he began to wonder why the concrete was not mixed on top of the embankment and thrown down. One noon he asked the foreman to explain the reason for mixing the material below and casting it up. The answer was that the water (used in mixing) did not have head enough in the pipe to carry to the top of the embankment! Here were some thirty men, each of whom were doing about a dollar's worth of work a day, and so causing a loss to the contractor of fifty cents daily on each man, and all because a small steam pump had not been installed. The young man finally decided to go direct to the contractor and offer to do with 20 new men as much as had been done with 30. The request was granted, and by merely installing a small pump so that the gang could mix on top of the embankment, the young man did exactly what he had promised to do.

It seldom happens that an opportunity comes so quickly or is so quickly seized when it comes. This young engineer saw his chance to prove that he had executive ability, and his employer was not slow to recognize it. Had be been engaged as a surveyor it is not unlikely that he would have had "nice, clean work," and quite as likely he would still be having the same "nice, clean work." High school graduates rush into clerkships, young engineers into offices and field parties. The young man seems averse to doing work that might be considered beneath him. Nothing could show less breadth of vision. If the young man really has ability it will show up best by comparison with those who have it not. Obviously the laborer who has all his life thought only of "next pay day"—obviously such a man is one by the side of whom the least capable of engineers will be a mental giant. Foremen in shops and in the field are generally workmen that have "graduated" from the pick and shovel university, and, having had their eyes set upon "next pay day" since first they can remember; they, too, are apt to lack in initiative, in ingenuity and in executive ability of a high order. The young engineer, therefore, if he is not afraid of dirt, should be able to compete with such foremen and rapidly prove his superiority. And, fortunately, in such a contest, the employer will see the results at the end of the first month after he has paid his men and received the "monthly estimate" check.

There are many who have taken courses in engineering because they fancy that they will like the work of designing structures or of locating railways. To those we would suggest that there is a field for the exercise of all of one's ingenuity in a managerial capacity, and it is a field as broad and ultimately as attractive as that of the engineer who designs a bridge or plans a pavement.

To handle men most effectively requires as much study and as much exercise of ingenuity as to design a dynamo. In the one case the engineer seeks to save labor directly, in the other case he seeks to save it indirectly.

The engineer as a manager need not forget what he has learned of theoretical mechanics or of descriptive geometry. Being thrown in daily contact with machines as well as with men, he sees the defects of the one quite as quickly as the defects of the other. And here it is that the engineer has a special opportunity to show himself a better manager than the man without a technical training. Having perfected the organization of his force of men with the tools at hand, he should next seek to perfect the tools. The untrained manager will ordinarily rest satisfied when

he has brought to perfection the handling of the men and plant with which he is provided; but the engineer will not rest there. He will study the plant itself. He will experiment with a view to improving the elements of that plant, even if to do so he must himself invent new appliances. He will not guess at efficiencies, he will measure them, and he will know whether his success is real or imaginary.

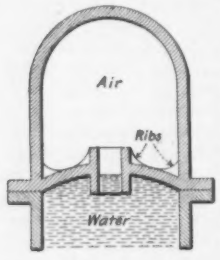
That the engineer with business ability is doing these very things is well known. The very fact that those in charge of large industrial works are looking among engineers for their heads of departments, proves conclusively that the men best able to judge have decided in favor of the technically trained engineer.

The organization of the great industrial combinations, known as trusts, has hastened the day of engineering supremacy in the industrial world. The trend of the times is apparent, and he that would reap the greatest harvest will find his field not where the "nice, clean work" abounds, but where the dirt is thickest and sweat runs fastest.

LETTERS TO THE EDITOR.

Air Chambers of Pumps.

Sir: In reply to M. A. G., Birmingham, Ala., who inquires regarding the shape of air chambers on pumps, writer can state that a straight air chamber without a neck is as efficient as the one with a narrow neck. But, as in the straight chamber a large surface of water is exposed to compressed air, the latter will be absorbed by the water in a short time. Consequently, the efficiency of the pump will be reduced, because air will have to be sucked in by a cock provided for this purpose, through the suction pipe. On many large pumping engines, which have apparently straight air chambers, the bottom is closed and for reasons stated only a small opening left, as shown in sketch.



E. F. N.

Racine, Wis., April 11, 1904.

The Maximum Weight of Crowds.

Sir: In your issue of April 14 there appeared an article by Prof. L. J. Johnson describing some recent experiments upon the maximum weight of a crowd of people. The writer recently made a similar experiment and obtained a result in close agreement with that reached by Prof. Johnson. This experiment consisted of packing into his office a crowd of students taken at random from the three upper classes at the Massachusetts Institute of Technology. The area of the room used was 87.3 sq. ft., gross, no deduction being made for several projections which interfered somewhat with the closest possible packing. Into this room 83 men were put and there was still room for several others near the door. As no more men were readily available at the time no effort was made to fill up this gap. The total weight of the men was 12,443 lbs., an average of 149.9 lbs. per man and of 142.5 lbs. per sq. ft. of floor. Except in the immediate vicinity of the door, this crowd was very dense and probably could not have been appreciably increased.

In Prof. Johnson's article were several quotations, all but one of which set the maximum load as much less than that given above. The following extract from the "American Architect" of April 15, 1893, was not given and should be included:

Professor Kernot, of Victoria, has recently made some important experiments on the weight of a crowd. It is a common idea among architects that people cannot, in practice, be crowded so closely together as to give more than about 90 lbs. weight per sq. ft. of the floor on which they stand, and there are traditions quoted in the professional books which would seem to indicate that, in order to get a load of a hundred pounds per square foot, it is necessary to lift up extra persons and drop them into the middle of a closely confined mass. Mr. Bindon B. Stoney, the distinguished author of a well known book on bridges and roofs, once packed 58 laborers, weighing, in all, 8,404 lbs., into the deck-house of a ship, the floor of which contained 57 sq. ft. This gave a load of 147.4 lbs. per sq. ft., each man, as will be observed, having a little less than 1 sq. ft. of standing room. On another occasion, he packed 73 men, weighing, in the aggregate, 10,948 lbs., into a wooden hut, inclosing 77 sq. ft. of floor space. This gave 142 lbs. per sq. ft. average load, but Mr. Stoney thought that two or three more men could have been squeezed in. Professor Kernot tried a similar experiment with his class of young engineers, packing sixteen of them, weighing 2,455 lbs., into an area of 18 sq. ft. This made the average load 134.7 lbs. per sq. ft., but the youths agreed that "considerable vacancies" existed in the group, and that another man, if there had been one in the class, might have been put in. This would have given an average load of 143 lbs., and it seems to be settled that the weight of a dense crowd of men may easily reach this amount, and, indeed, in case of panic, might exceed it. Under these circumstances, the safe resistance of floors of public buildings, bridges, city railroad stations and other places where dense crowds may collect, ought not to be less than 300 lbs. per sq. ft., for it seems to be shown that the dead load may be nearly, or quite, 150 lbs., and the strain which would come on the floor by sudden movements of such a crowd would, according to the usual estimate, be double that due to the dead load alone.

While it is the writer's opinion that enough evidence has been given to show conclusively that the weight of a crowd of men may reach 150 lbs. per sq. ft., he does not wish to be considered as advocating the use of such a heavy load in the design of ordinary structures, although in some cases local conditions might make such an estimate a wise one. It should be noted that in the design of many highway bridges a uniform load of 100 lbs. per sq. ft. increased by impact is taken for the sidewalk and roadway. This is often equivalent to a quiescent load of 125 to 130 lbs., which would seem ample for nearly all cases.

Yours respectfully,

Charles M. Spofford.

Massachusetts Institute of Technology, Boston,
April 26, 1904.

(Our correspondent apparently failed to notice that on page 353 of the same issue in which Prof. Johnson's paper was printed we made editorial comment thereon and called attention to Prof. Kernot's experiments, which were described in Engineering News of March 16, 1893.—Ed.)

Effect of a Vacuum Against the Face of Overtopped Dams.

Sir: I have noted the recent discussions on the point raised by me in Engineering News of Feb. 11 (p. 130) regarding the additional pressure sustained by a dam when a partial vacuum is formed behind the sheet of falling water.

The tendency of the difference in air pressures on the two sides of the sheet, is, as Mr. Gould says (Eng. News, March 3, p. 204), to force the sheet back against the face of the dam.

Thus, in Fig. 1, let O N be the under side of the sheet when air is freely admitted under it. Suppose, now, a partial vacuum to be formed behind the sheet. The sheet will then be forced back by the air pressure to a new position, as O A.

But it does not follow that the sheet will be forced back as far as the face of the dam. The vacuum formed may not be sufficiently perfect; or, indeed, even assuming a complete vacuum could be formed, the velocity of the water over the dam might be so great, and the face of the dam so steep, that the atmospheric pressure might still be unable to change the path of the sheet sufficiently to cause it to hug the face of the dam.

If, however, the head of water over the dam is less, or the section of the dam extends further down stream, the atmospheric pressure may be and often is able to press the sheet against the dam as in Fig. 2. Only a part of the air pressure, then, is spent in deflecting the sheet from its natural course, O N, and the remainder is exerted through the sheet against the face of the dam, thus partially relieving the dam from the effect of vacuum.

The form of the dam might be such that the sheet (assuming the air to be entirely extracted from behind) would be forced back until it just touched the dam. Practically all, then, of the atmospheric pressure on the upper surface of the sheet would be expended in forcing the sheet back, practically no force could be transmitted through the sheet against the down-stream face of the dam, and the dam would have to resist practically the entire atmospheric pressure from behind.

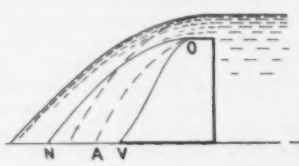


Fig. 1.

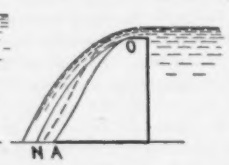


Fig. 2.

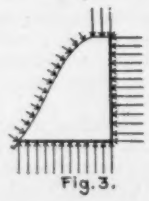


Fig. 3.

As to the degree of vacuum which actually obtains in practice, I should be glad to know the results of experiments, but I feel that it must frequently be enough to merit serious consideration.

All this suggests that in computing the stability, we should consider the entire atmospheric pressure on the top, back and bottom of the dam, but only the partial vacuum pressure on the face of the dam as indicated in Fig. 3. This gives a resultant (considering only air pressures) which has both a horizontal and vertical component as well. The "vacuum," therefore, should be considered as acting upon the downstream face of the dam, and not on the back or upstream face, as indicated in my preceding letter.

I fully recognize Mr. Gould's caution about pounding at the toe of the dam "which cannot be reduced to a mathematical formula," but the vacuum is another matter and one which, I believe, is capable of more or less exact treatment.

Yours truly,

John C. Trautwine, 3d.

257 South Fourth St., Philadelphia, Pa., April 11, 1904.

Shearing Stress in Concrete-Steel Beams.

Sir: Replying to Mr. Kahn's letter in Engineering News of April 14, the writer of an original letter to your journal occupies a very advantageous position. All replies that come in are submitted to him, and in every issue he has the last word, and can—whatever the merits of the discussion—if he so chooses, make such statements and misrepresentations as will produce, in the mind of the average reader, an entire misconception of the facts. In the present instance, one would gather from Mr. Kahn's articles, that the reason he is laying such stress on his system, is that it accomplishes wonderful results in the way of load carrying capacity in concrete-steel construction. The writer proposes to show (1) that Mr. Kahn's beam formulas are not only inadequate from a modern scientific point of view, but incorrect from his own point of view; (2) that assuming the ultimate strength at the elastic limit for beams reinforced with high elastic limit material is more scientific, cheaper and safer than assuming the ultimate strength of the beam to occur at the ultimate strength of low elastic limit material; (3) that a mechanical bond, such as furnished by corrugated bars, gives at least two and one-half times the bond furnished by plain material, even though the adhesion is not broken, and that Mr. Kahn's table would have shown this if he had copied correctly the values given in the original table from which his results were obtained; (4) that shearing provision, *where shearing provision is necessary*, is more readily supplied with individual bars than with the Kahn bar; (5) that so far as his published tests have shown, his beams have not carried more than one-third what properly constructed beams of the size indicated should have carried, and that if remarkable at all, they are remarkable for their weakness rather than for their strength.

FORMULA.—Mr. Kahn disclaims his formula, saying that it was taken from an article by Prof. J. B. Johnson, in Engineering News, of Jan. 3, 1895. This formula was about the earliest discussion to appear in this country, and was later revised and presented by Professor Johnson at the Detroit meeting of the American Association for the Advancement of Science in August, 1897. This paper was abstracted in Engineering News for Oct. 21, 1897. This latter discussion was a more elaborate development of the subject, but like the former, was a straight-line formula, not taking into account the curvature of the concrete compressive stress diagram. The writer would suggest that Mr. Kahn go to the later formula for a more satisfactory analysis, were it not that Professor Johnson stated in his paper that the writer was the author and first user of same. In Professor Johnson's article in Engineering News of Jan. 3, 1895, he considers three cases. Case 1 is applicable up to the time that the concrete reaches its tensile strength on the extreme fiber. Case 2 is for compression failure, and Case 3 is for failure of the metal. In Cases 2 and 3, he is unable to locate the neutral axis by his method of discussion. In Case 1, the neutral axis can be located, and he describes the method with which we are all familiar, of transforming the section into its equivalent in concrete by building out wings opposite the plane of metal reinforcement; but he does not give the location of the neutral axis for this case by means of an equation. For the purpose of locating the neutral axis, Mr. Kahn adopts the method described by Professor Johnson in his Case 1, but seems to make a mistake in his calculations, as he does not come out with the correct result. In his catalogue, his equation for locating the axis is:

$$y = \frac{15a + bd^2}{30a + 2bd};$$

where y = the distance from the center of the metal reinforcement to the neutral axis; a is the area of the metal in square inches; b the width of the beam; d the depth of the beam to the metal; and where the ratio of the modulus of elasticity of the steel to the modulus of elasticity of the concrete is assumed to be 15. Using Professor Johnson's method, and Mr. Kahn's terms, the latter's equation should read:

$$y = \frac{bd^2}{30a + 2bd}.$$

Also, in obtaining the value of his moment of resistance, he takes for the moment of metal his center of moments at an assumed center of compression above the neutral axis; while for the moment of the concrete tensile forces, he takes his center of moments at the neutral axis. The sum of these two he calls the moment of resistance.

In view of the above facts, the writer thinks that Mr. Kahn has not followed Professor Johnson closely enough to be noticeable, and if he had, he would not have a satisfactory formula from the modern standpoint, as Professor Johnson—as above stated—assumed a constant modulus of

elasticity for the concrete, which we now know to be far from the truth. Mr. Kahn says he makes allowance for the change in modulus, but it is not apparent in his equation for the location of the neutral axis. He assumes a constant ratio between the moduli of the steel and the concrete, which involves a *fixed* position for the neutral axis, which position is that where it starts (or it would be except for the mistake in his figures). As a matter of fact, the neutral axis remains at the position that he has assumed only until the concrete has reached its ultimate strength in tension on the extreme fiber; which of course

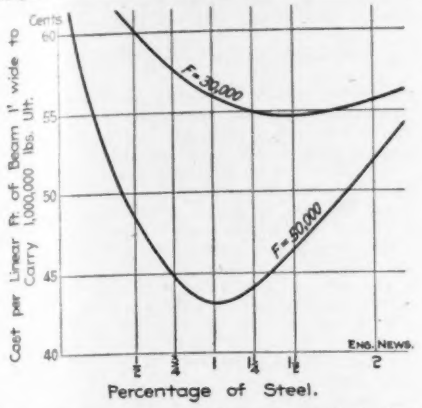


Fig. 1. Diagram Showing Economy of High Elastic Limit Steel for Reinforcing Concrete.

F = elastic limit of steel.
Crushing strength of concrete = 2,400 lbs. per sq. in.
Cost of concrete in place, excluding forms taken at 22 cts. per cu. ft.
Cost of steel in place taken at 2¾ cts. per lb.

occurs under a very light load, in many cases under the dead load alone. It does *not* remain stationary until the elastic limit of the metal is reached as stated by Mr. Kahn. With the falling off of the increase in the concrete tensile forces with the additional load, the neutral axis is forced to rise to preserve the equality of the forces above and below the axis, and continues to rise at a more or less uniform rate of speed, until we strike the curved portion of the concrete compressive stress diagram, when the upward movement is checked, and eventually stopped altogether, at about the time the maximum load is being carried in a properly reinforced beam.

To locate this final position of the neutral axis at the maximum load is not difficult, even though we take into

Ordinary Method for Deep Beams.
Fig. 2.

consideration the curvature of the stress diagrams in tension and compression, and is the method employed by the writer, by which he obtains a formula for the ultimate strength of concrete-steel beams, no more difficult to handling than Hook's law for rectangular beams of constant modulus and homogeneous material. Mr. Kahn seems to have no formula at all for T-sections, though he apparently has built no other kind.

ELASTIC LIMIT.—The material that the writer recommends for steel-concrete work is of the same chemical composition as that from which all steel rails are made, which are certainly subjected to much more shock than would be, for example, the reinforcing bars in a steel-concrete culvert passing under the track. The proposition is

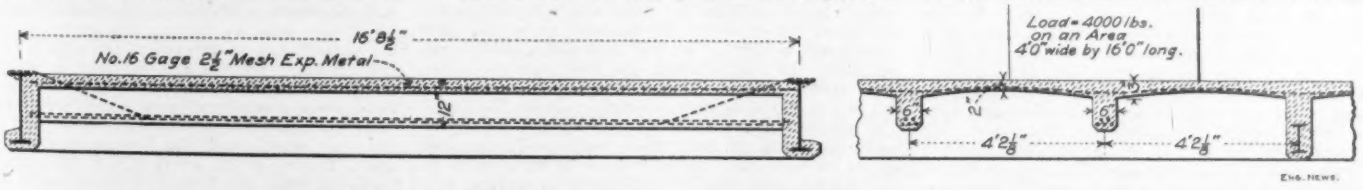
TABLE I.—RESULTS OF TESTS ON THE UNION BETWEEN CONCRETE AND STEEL.
Made at Massachussetts Institute of Technology.

No. of Test.	Type of Rod, in.	Size of concrete block, in.	Length of rod imbedded in concrete, in.	Breaking load, lbs.	Min. area of cross-section of rod, sq. in.	Shearing stress in lbs. per sq. in. of net section.	Stress on rod in lbs. per sq. in. of net section.	Stress on rod in lbs. per sq. in. of net section per lin. in. of imbedment.
1	Ransome ½	6 x 6	12	12,100	0.25	504	48,400	4,000
4	Ransome ½	8 x 8	12	8,300	0.25	346	33,200	2,750
13	Thacher ½	6 x 6	12	4,850	0.18	270	26,900	2,240
22	Johnson ½	6 x 6	12	12,200	0.14	678	87,200×	7,300
2	Ransome ½	6 x 6	16	8,100	0.25	253	32,400	2,020
5	Ransome ½	8 x 8	16	14,000	0.25	438	56,000	3,500
14	Thacher ½	6 x 6	16	8,200	0.18	340	45,500	28,50
23	Johnson ½	6 x 6	16	13,120	0.14	545	93,700×	5,850
3	Ransome ½	6 x 6	26	16,800	0.25	323	67,200	3,580
6	Ransome ½	8 x 8	26	15,000	0.35	288	60,000	2,320
15	Thacher ½	6 x 6	26	10,550	0.18	72	58,600	2,250
24	Johnson ½	6 x 6	26	13,750	0.14	354	98,400×	3,790
7	Ransome ⅝	8 x 8	20	25,900	0.56	431	46,300	2,315
16	Thacher ⅝	8 x 8	20	21,150	0.39	478	53,000	2,650
25	Johnson ⅝	8 x 8	20	27,600	0.31	619	89,100×	4,455
8	Ransome ⅝	8 x 8	24	31,900	0.56	443	57,000	2,370
17	Thacher ⅝	8 x 8	24	18,300	0.39	344	45,900	1,910
26	Johnson ⅝	8 x 8	24	25,000	0.31	467	80,600×	3,360
31	⅝ round	8 x 8	24	15,300	0.44	271	38,400	1,600
34	⅝ square	8 x 8	24	19,700	0.56	274	35,200	1,470
37	1⅛ x ⅛	8 x 8	24	12,400	0.56	159	22,100	920
40	1⅛ x ⅜	8 x 8	24	20,300	0.56	226	36,300	1,520
43	2¼ x ¼	8 x 8	24	5,000	0.56	42	8,930	373
32	⅝ round	8 x 8	31	18,600	0.44	255	42,200	1,360
35	⅝ square	8 x 8	31	22,600	0.56	243	40 400	1,300
38	1⅛ x ⅛	8 x 8	31	20,300	0.56	201	36,200	1,170
41	1⅛ x ⅜	8 x 8	31	21,700	0.56	188	38,800	1,250
44	2¼ x ¼	8 x 8	31	25,500	0.56	165	45,500	1,470
9	Ransome ⅞	8 x 8	36	36,600	0.56	339	63,500	1,760
18	Thacher ⅞	8 x 8	36	23,700	0.39	297	59,400	1,650
27	Johnson ⅞	8 x 8	36	28,000	0.31	483	90,500×	2,510
33	⅞ round	8 x 8	36	18,600	0.44	219	42,200	1,170
36	⅞ square	8 x 8	36	23,900	0.56	221	42,700	1,180
39	1⅛ x ⅛	8 x 8	36	21,700	0.56	185	38,700	1,070
42	1⅛ x ⅜	8 x 8	36	22,130	0.56	164	39,500	1,100
45	2¼ x ¼	8 x 8	36	26,100	0.56	145	46,600	1,290
10	Ransome 1⅛	10 x 10	27	33,100	1.27	273	26,100	970
19	Thacher 1⅛	10 x 10	27	28,100	1.03	288	27,300	1,010
28	Johnson 1⅛	10 x 10	27	40,100	1.00	371	40,100×	1,480
11	Ransome 1⅛	10 x 10	37	26,150	1.27	157	20,600	556
*20	Thacher 1⅛	10 x 10	37	48,950	1.03	367	47,500	1,290
29	Johnson 1⅛	10 x 10	37	44,200	1.00	300	44,200×	1,200
12	Ransome 1⅛	10 x 10	50	34,600	1.27	153	27,200	545
21	Thacher 1⅛	10 x 10	50	58,450	1.03	324	56,700	1,130
30	Johnson 1⅛	10 x 10	50	57,250	1.00	286	57,250×	1,140

*The bond on these bars was not measured, the blocks being torn apart by indirect stresses.

longer in dispute. This economy can be illustrated by the accompanying diagram (Fig. 1) which was presented by the writer in a discussion of the subject before a recent meeting of the Western Society of Engineers. From this diagram it will be noticed that the most economical rectangular beam to carry 1,000,000 inch-pounds ultimate bending moment, is with 1.5% reinforcement for soft steel, and 1% for steel having an elastic limit of 50,000 lbs. The concrete is assumed to be of good quality, having a crushing strength of 2,400 lbs. per sq. in., or what the writer calls, in his catalogues, "special concrete." Where average concrete, having a crushing strength of 2,000 lbs. per sq. in., is used, the percentage of metal will be slightly less. From the above it will be seen that where the low elastic limit material is used, the beam will cost 28% more per lineal foot than where the high elastic limit material is employed. At the Chicago meeting, the objection was made to the use of the high material, that if the concrete would only take a proportionate elongation of 0.0010, which corresponded with an elastic limit of 30,000 lbs. per sq. in., there was no advantage in using material having an elastic limit greater than this. To this the writer replied that some of the beams tested at Terre Haute gave a proportionate elongation, at first crack, of 0.0015, which corresponds with an elastic limit of 45,000 lbs. per sq. in., and many of the beams did not give material cracks until the elongation on the bottom had reached as much as 0.0018, corresponding with an elastic limit of 54,000 lbs. per sq. in. Very dry concrete will not stretch as much as wet concrete. There is therefore less desirability for high elastic limit in floor construction than there is for out-door structures; but as by thousands of tests it has proved itself thoroughly reliable, and as it costs no more per pound, and takes only two-thirds as many pounds, it is a much more desirable material to use, even in building work.

MECHANICAL BOND.—Mr. Kahn makes the statement that results of the tests on adhesion at the Massachusetts Institute of Technology show "that the adhesion per square inch of metal per lineal inch of embedment in concrete, for a plain bar, would be equally as efficient as a corrugated one." He then proceeds to tabulate some values which are derived from the above table, but in assigning the area to the ⅞-in. corrugated bar, he calls this ⅝-in., taking the area probably, from the catalogue, whereas the area of the bars actually tested was as given in the report, viz.: 0.31 sq. in. This would give a value of 2,500 for the adhesion per square inch of metal per lineal inch of embedment—or about two and one-half times the values for plain bars—instead of 2,072, the value given by Mr. Kahn. The other two values given for the adhesion per lineal inch of the corrugated bars, are for the 1¼-in. size, one of these being for a depth of embedment of 27 ins., and the other for a depth of 50 ins. If he had read the article that was attached to the table, he would have seen that the values obtained on the large sized bars of all kinds were not satisfactory, and not representative of the bond, the concrete having been split by indirect stress, due to imperfect bearing in the testing machine. The blocks in which they were embedded were altogether too small to test bars of such great strength, and the values obtained on these were stated by Professor Spofford to be unsatisfactory, and not representative of the value of the mechanical bond on these sizes. It is wholly unfair, therefore, for him to use the results on these sizes to



Longitudinal Section. Cross Section.

FIG. 3. DETAILS OF STANDARD SLAB AND BEAM FLOOR USED BY A. L. JOHNSON.

not at all comparable with that of a steel bridge in which the material is punched, and when the writer says that it is perfectly safe to use such material in concrete-steel work, he speaks from knowledge. Out of the hundreds of thousands of pieces that have been used by his company, thousands of which, in large sizes, have been bent cold, as stated in his former letter, there has never been a failure on account of the brittleness of the material, nor on account of any flaw therein, and there is therefore no reason why the designing engineer should not avail himself of the large economy that can be effected by the employment of such material. Among scientific men most familiar with this subject, this is not a point that is any

make his comparison, especially as on the only other result which could have been called at all fair, he made a mistake as above indicated. Omitting the large-sized bars which had depths of embedment up to 50 ins., and which were, as above stated, improperly tested, and comparing depths of embedment and sizes of bars similar to the depths and sizes used on plain material, we have the values shown in Table II., in which the effect of the mechanical bond of the corrugated bars especially, is very manifest. Until the publication of these tests made at the Massachusetts Institute of Technology, the writer had never supposed that there would be any particular advantage in the mechanical bond until the adhesion was injured or de-

stroyed, and he provided it only to take care of the possibility of such an occurrence. But the above tests showed the immensely greater reliability of a good mechanical bond from the very beginning. Those who have had the most experience in the line know that rupture of the adhesion often does happen, and can point out specific cases where it has occurred; and it is a point which the writer does not care to argue with Mr. Kahn. European engineers also are coming around to this position, and no doubt for good cause.

SHEARING PROVISION.—With regard to what the writer said in his last letter, to the effect that there was no necessity for shearing provision in the beams illustrated by Mr. Kahn in his letter published in the Engineering News of Feb. 18, Mr. Kahn says that these beams had a ratio of height to length of 1:18, which ratio he emphatically declares is not abnormal. Nobody ever said that it was, so far as the writer is aware. The writer considers such a ratio perfectly normal. He merely says that in such beams there is no necessity for shearing provision, as they would never fail by shear; nor would he consider that any necessity for shearing provision, under uniformly distributed load, would exist until the ratio of depth to height became greater than 1:10, where reasonably good concrete was used. When, therefore, Mr. Kahn illustrates the complexity of using what he calls the "Locher construction" (as to which the writer must confess absolute ignorance) on beams 15 ins. deep, having a span of 25 ft. and finds that with this construction, to have shearing provision continuously from end to end, eighteen individual bars would be required, he becomes, in the writer's estimation, unnecessarily strenuous. Instead of reinforcing bars turned up at eighteen different points, the writer would use one or two horizontal pieces not turned up at all; because such a beam, with only horizontal reinforcement, would not shear. Taking a beam 12 ins. wide by 15 ins. deep, on a 12-ft. span, which for average concrete would require 1.1 sq. in. of high grade metal; the writer would use three ¾-in. bars, in two lengths, one length passing straight through horizontally, the other two bent up as shown by bars 2 and 3 in the writer's Fig. 4 of his previous letter, and which is herewith repeated as Fig. 2; the third shearing provision, indicated by bar 4, in this case, not being necessary. Many structures have been built, and are now building, on railway work, after this method, and no difficulty whatever has been found in the construction. Mr. Kahn is fearful that the eighteen bars which he thinks would be necessary in the above construction, would be so close together as to cause the breaking off of the concrete below the bar. As three bars are all that are necessary, this fear would naturally be groundless. But while on this subject, many concrete constructions in engineering work require two or three times the quantity of metal reinforcement that it would be possible for Mr. Kahn to obtain in one layer without placing the bars practically side by side, in which case the bottom layer of concrete certainly would drop off, and he has so far not indicated how he would use his bars in two and three layers. In such case it would probably be necessary very often to omit the shearing up of the bars in the lower layer, using these as plain rods.

Mr. Kahn is much concerned regarding the date of the writer's first consideration of shear, and is disposed to dispute the writer's statement, made in his first letter, that he had recognized the necessity for some shearing provision in deep beams, as much as eight years ago. The writer takes it that this is a matter that is not pertinent to the subject in hand, and is not really worthy of a reply. However, he will say that he had the pleasure of reading, in the fall of 1895, a book on some experiments on concrete-steel beams, by Thaddeus Hyatt, published in 1877, the experiments having been conducted at Kirkaldy's Laboratory, throughout the year of 1876. Some of these experiments had bars bent up towards the end of the beam, and demonstrated the advantage of this form of construction. The writer did not have any occasion, however, to use shearing provision in his work, not building deep beam forms, until 1898, when he put in a rib floor, with some of the bars running through and some coming diagonally up at the ends and hooking over the beam.

FIG. 4. TEST OF JOHNSON REINFORCED CONCRETE FLOOR OF 16 FT. 8½ INS. SPAN, LOADED WITH 600 LBS. PER SQ. FT., OR 40,000 LBS. ON ONE RIB. DEFLECTION, ⅛-IN.

COMPARISON IN RESULTS.—A man should be judged by his works. With this criterion, it is difficult to understand what all the noise that Mr. Kahn is making is about. The beam tests which he has described carry at complete rupture, *only about one-third the load tha they ought to carry at the elastic limit* of the metal. For example, take the beam illustrated in his Figs. 6, 7 and 8, Engineering News, April 14, where he has a T-section floor, the flat slab being 2 ins. thick, with five ribs underneath, 4 ins. wide by 8 ins. in depth, the span being 15 ft., the load carried at the elastic limit of the metal was 44,000 lbs. If properly constructed, this load should have been 128,000 lbs. at least. This is the theoretical capacity of the construction, according to the writer's formula for T-shaped beams, which have been tested in actual practice, and which are illustrated herewith in Fig. 3. In this construction the ribs were 6 ins. wide by 9 ins. deep, spaced 4 ft. 2½ ins. apart, with a slab on top 2 ins. thick at the center and 3 ins. thick at the rib, the center of the metal reinforcement being 2 ins. above the bottom of the rib. The span was 16 ft. 8½ ins. Comparing this with Mr. Kahn's construction, the ribs on the writer's tests were 1 in. deeper, but the metal was 2 ins. above the bottom of the rib, which was probably higher than Mr. Kahn's bar in his test, so that the effective depth could not have been very different. The floor plate was somewhat thicker than his for a short distance near the rib, but was of the same thickness throughout the main portion thereof. The writer's ribs were 6 ins. wide, as against 4 ins. in Mr. Kahn's construction, but the width of the rib itself cuts very little figure in the strength of the T-beam. The span in the writer's construction was 16 ft. 8½ ins., as against 15 ft. for Mr. Kahn's tests. Before the writer's floor was tested, the construction was cut entirely in two, parallel to the rib under test, so as to prevent any cross-arching action, though this was not really necessary, owing to the thinness of the floor plate. Although the test was erected on the floor beams of a building, the test floor was put in before the work was done, and there was therefore no floor in the ... els to help out by allowing the section ... any interior arching action parallel to ... case this is not great on T-section floors ... effect there might have been did not ... The load was 420 sacks of cement pla... the rib, overlapping the same 1 ft. 9 ins. ... extending from end to end of rib. Est... at 95 lbs., this gave a total load of 4... which there was a deflection of the rib ... was satisfactory, and the load was not ... tion. A part of this load was transfe... cent ribs, represented by $\frac{10.5}{50} \times 17{,}500$ ... transferred to each rib, leaving on the ... 32,640 lbs. There was undoubtedly some ... of the load, but it could not have be... amount under such a slight deflection a...

The test shown by Mr. Kahn was at ... 44,000 lbs., and at the ultimate 65,400 ... giving 8,920 lbs. on one rib at the elastic ... 000 lbs. at the ultimate, where his deflection ...

Now there is very little difference between the theoretical capacities of the two constructions, the greater span of the writer's rib offsetting its possibly slightly greater depth, supposing that the metal was at the same distance from the bottom of the rib in the two cases. But the *corrugated bar rib carried* 32,640 *lbs. with* ... *deflection*, and the *Kahn rib* 13,080 *lbs. with* 20 *ins. deflection*. The same argument applies to every test he has so far made, and the writer will agree to duplicate every one of them, using beams of the same size reinforced with corrugated bars, according to his regular method as herewith shown, and carry three times the load at the elastic limit, and twice the load at the ultimate strength that was carried by any of the beams which he has reported.

His comparisons have so far been made with results on twisted bars of large size, in which but a very small twist can be obtained, which bars exercise a great splitting tendency on the concrete, and are not representative of what can be done, even on plain material, so long as the adhesion is intact, and certainly not representative of corrugated construction.

Replying to Mr. Goldenberg's letter I will say that his remarks are all based upon his deduction, from the Massachusetts Institute tests on adhesion of different kinds of bars, that a 1¼-in. bar had no more hold in concrete per inch of imbedment than a ½-in. bar. If you imbed the 1¼-in. bar deep enough and then divide by the depth of imbedment this will be true, even though the bar be broken. Does Mr. Goldenberg think that a 1¼-in. bar imbedded 12 ins. in concrete will have no more holding power than a ½-in. bar imbedded the same amount? That is the equivalent of what he says. The results on the 1¼-in. bars were not satisfactory, the effect of the bond on these not being measured, as stated in reply to Mr. Kahn. A load of from twenty to thirty tons in these specimens was applied at one section of the concrete instead of a gradual increase or decrease of stress, as would occur in practice, and the blocks were broken by indirect stresses having no relation to the bending value. All the results are candidly published by the writer's company, however, with the expectation that the article will be read without blind prejudice, in which case the condition will be understood, as it is there described.

By referring to the original table (see Table I.), it will be found that none of the corrugated bars, exclusive of the 1¼-in., had a sufficiently *short* imbedment to develop less than, or only as much as, the elastic limit of 55,000 lbs. per sq. in., but all were stressed up to at least 80,000 lbs. If the depths of imbedment had been kept down to only just enough to develop the elastic limit of the bars, which is considered the ultimate load in practice, the results per lineal inch on the corrugated bars would have been two or three times as much. Tests for the determination of the effect of particular forms of mechanical bond should be made on short lengths of imbedment, and not upon such lengths as develop secondary stresses whose value and effect cannot be determined.

In no beams reinforced with corrugated bars, have the bars ever pulled out of the concrete, as Mr. Goldenberg fears. If shear failure occurs, it is in the concrete in the horizontal plane just above that of the metal reinforcement, so that Mr. Goldenberg's theoretical discussion is not only incorrect theoretically, but it has no practical application. But even his own formula indicates that such failure as the pulling out of the corrugated bars would never occur. If the ½-in. or ¾-in. sizes had been tested in depths of imbedment just sufficient to develop their

TABLE II.—STRESS ON RODS IN LBS. PER SQ. IN. OF NET SECTION PER LIN. IN. OF IMBEDMENT.

Kind of Bar.	Depth of Imbedment. 12"	16"	20"	24"	26"	31"	36"
	Size of Bar. ½"	½"	¾"	¾"	½"	⅝ square and flats having same area.	¾"
Plain				1,176		1,310	1,162
Ransome	3,375	2,760	2,315	2,370	2,450	[illegible]	1,760
Thacher	2,240	2,850	2,650	1,910	2,250	[illegible]	1,650
Corrugated	7,300	5,850	4,455	3,300	3,790	[illegible]	2,510
*Interpolated.			2.86×		2.4×	2.16×	

elastic limit, the adhesion or bond per lineal inch would certainly have been much higher, as before stated. But let us take the ⅜-in. size at the adhesion value given in the table, 12, 1,000 lbs., which is the value assumed by Mr. Goldenberg. In the case he assumed, the beam was practically 12 ins. wide by 12 ins. deep and was required to have a net section of 1 sq. in. of metal. This would require—say seven ½-in. bars, each having a net section as given in the table, of 0.14 sq. in. Mr. Goldenberg's formula is

$$W = 2gd,$$

where W = total uniformly distributed breaking load on the beam in pounds;

g = holding force of the bar in pounds per inch of imbedment;

d = distance from the center of metal reinforcement to center of compression above the neutral plane.

For the seven ½-in. bars above, g becomes 7 × 1,000 = 7,000 lbs.; d is 10 ins., and thus we have

W = 2 × 7,000 × 10 = 140,000 lbs. Then the safe load = ¼ W = 35,000 lbs., instead of 5,000 lbs., as he shows in his figure. In other words, his horizontal line would be entirely beyond the limits of his diagram, and a 12-in. beam would have to be tested on about a 4-ft. span, or less, before there would be any danger of the pulling out of the corrugated bar reinforcement.

Using the ¾-in. bar, the value given for this bar in Mr. Goldenberg's table for 20 ins. imbedment, which is probably twice as much as was necessary, is 1,329 lbs. per in. Now the value for the proper depth would certainly be not less than 2,500, but let us assume 1,500. The area of these bars is given as 31 sq. ins., so that it would take 3½ bars to make 1 sq. in., which would give g = 5,000, and 2gd = 100,000 lbs., and the safe load at 25,000, or 250 hundred, instead of 50 hundred as shown in Mr. Goldenberg's table.

Mr. Goldenberg considers it an important fact, noted in the Kahn bar, that the ultimate capacity of the steel was invariably taxed. It is this fact that differentiates it primarily from all other kinds of reinforcement in the opinion of Mr. Kahn also. But the reason he so readily breaks his metal is on account of a rank defect in design, which if made in using plain corrugated, or any other kind of bar, would give the same result in the development of the ultimate strength of the steel. A sheet of expanded metal imbedded in a 4-in. rock concrete slab will be pulled entirely apart when the slab is tested.

A. L. Johnson, M. Am. Soc. C. E.

Century Building, St. Louis, Mo., April 12, 1904.

Notes and Queries.

J. A., Scottdale, Pa., asks whether a green sand casting is any stronger than one cast in dry sand, and if so, why?

According to Bolland's "The Iron Founder" (p. 236): "The soundest castings are those which are poured with the hottest iron. . . . This, I think, is a very strong argument in favor of dry sand molds for all work requiring the maximum degree of strength and purity. . . . Dry sand molds may be poured with much hotter iron than green sand molds, without detriment to the surface of the casting."

S. F. W. writes:

I am anxious to learn what may be considered the smallest openings which an engineer may put in for culverts, bridges, etc., for various drainage areas, without incurring unnecessary expense for large openings and without incurring danger to roadbed or adjacent property from floods, etc., through making the opening too small.

The question of culvert area was discussed very fully in a report presented at the 1897 meeting of the Association of Railway Superintendents of Bridges and Buildings (Eng. News, Oct. 21, 1897). Other references in this connection are as follows: Engineering News, May 30, 1901 (p. 406); Nov. 6, 1902 (p. 386), and Dec. 25, 1902 (p 534).

AN OLD REGULATION FOR CONCRETE BUILDING WORK IN LONDON.

The rapid development of concrete-steel construction in recent years tends to make us forget the fact that ordinary concrete, without any steel reinforcement, has a not unimportant field of usefulness, not merely in foundations or other massive construction, but also in light superstructure work. In Europe, where the "frame-house" is little known because lumber is much more costly than here, concrete has been used rather widely for the construction of walls of dwelling-houses as well as business buildings. Such walls, like those of brick or stone masonry, are never subjected to direct tension, and only in negligible degree to bending. There is no reason, then, for embedding steel bars in the concrete (unless they be thought desirable as a protection against shrinkage cracks), so that the cheaper wall of plain concrete is quite adequate.

Twenty or thirty years ago, of course, the question of using concrete in America was involved with conditions quite different from those prevailing to-day. Lumber was much more plentiful and cheaper than it is to-day, while cement was a costly article. Now that the immense development of the Portland cement industry has brought the best cement to prices much below those asked for natural cements two decades ago, the position of concrete as a building material in competition with wood, brick and stone is vastly improved.

The use of concrete in city building work, however, is somewhat hampered by the fact that municipal building laws usually fail to recognize and permit this material. In contrast herewith, most European building codes contain a section permitting and regulating its use. Our attention has been called by one of our readers to the regulations of the city of London, adopted by the Metropolitan Board of Works nearly thirty years ago, and we reprint these regulations below. While not what would be required to-day, this old regulation is in several respects very good, and may be read with profit even now. The clause requiring a grouting of 1:2 mortar between successive layers of concrete is especially worth noting.

CONCRETE BUILDINGS.

Regulations of the Metropolitan Board of Works, London.

Whereas, by the Metropolitan Building Act, 1855, it is provided that buildings to which the rules enacted in the schedules in that act relative to the construction and materials of walls are inapplicable, require the special sanction of the Metropolitan Board of Works.

And, whereas, it has been shown, to the satisfaction of the said Board, that buildings of certain moderate dimensions may be advantageously constructed of Portland cement concrete, compounded with proper attention to the quality of the cement and the proportion thereof to the concrete materials, and to the due application of a mould or machine for giving coherence to the work during its progress.

Now, therefore, the Metropolitan Board of Works do hereby approve of and license the use of Portland cement concrete in the construction of the houses aforesaid, subject to the conditions following, viz.:

1. The Portland cement shall be of the very best quality, ground extremely fine, and weighing not less than 112 lbs. to the striked bushel, and capable of maintaining a breaking weight of 350 lbs. per square inch seven days after being made in a mould, and immersed in water during the interval of seven days. Such test, when necessary, and ordered by the District Surveyor, to be made at the works of the Metropolitan Board.

2. The other materials of the concrete to consist of clean Thames ballast, or of gravel, or crushed slag from furnaces, or smiths' clinkers, or broken glass, crockery, brick-burrs, or small broken stones, or any hard and durable substance; and each to pass through a screen or mesh not exceeding 2 inches diameter. Sand to be added to such materials in the proportion of one to two. All such materials to be perfectly clean, and free from all greasy, loamy, or clayey matter, and, if necessary, to be washed.

3. These materials and cement to be mixed in the proportion of not more than six parts of material as aforesaid by measure, to one part by measure of the best Portland cement.

4. In making the concrete, a box, 2 feet by 4 feet by 2 feet, or other like proportions, is to be used for the materials and another box capable of holding one sack or half a sack containing two bushels of the cement. The cement and materials are to be turned over at least three times, and thoroughly mixed together with water.

5. The concrete thus composed is to be laid into the walls of the buildings all round in equal layers, and grouted with cement in the proportion of one cement to two of clear, washed sharp sand, after each layer, until the walls are completed in height. The grout to be made as mortar first, and then thinned with water to the necessary consistence.

6. The above materials and matters are to be well and thoroughly bound together, and fixed and applied by one or other of the processes now in use for concrete building, so that security shall be provided for the complete coherence of materials and work during its progress, and to guard against the delay, risks, and errors of the work being put up otherwise than by a well-arranged mould or machine.

7. The thicknesses of walls to be equal, at the least, to the thicknesses for brickwork prescribed in the Building Act.

8. Suitable cores to be provided for fireplaces and for connecting them with flues, and also for recesses and flues; or flues may be formed with tubes of earthenware.

9. Door and window frames to be built into the walls.

10. The rules of the Building Act as to the use of timber in walls, and that statute generally to be observed as in ordinary buildings.

11. Such concrete buildings to be carefully supervised by the District Surveyor, and his fees in respect thereof to be one half more than the scheduled fees provided by the Building Act for new buildings or additions. The fees for alterations to be only as scheduled.

TO IMPROVE THE QUALITY OF SAND-LIME PRODucts the German Association of Sand-Limestone Manufacturers at its meeting in February decided to have the products of all its members systematically tested by disinterested experts. Members whose products run lower than 140 kg. per sq. cm. (2,000 lbs. per sq. in.) in compressive strength are to be expelled from the association. A similar method was adopted by the Association of German Portland Cement Manufacturers a number of years ago to maintain the standard of quality of Portland cement.

THE AUSTRIAN COMPETITION FOR CANAL LIFTS which closed March 31 of the present year brought out over two hundred separate designs. The jury consists of Messrs. Ast, de Bovet, Doerfel, Vernon-Harcourt, Hermann, Hochenegg, Riedler, Taussig and Veiflik.

UNIFORM ACCOUNTING IN ITS RELATION TO COMPARATIVE MUNICIPAL STATISTICS.*

By L. G. Powers.†

In 1899, under provision of a special Act. of Congress, the U. S. Department of Labor began the annual collection and presentation of the social statistics of cities with over 30,000 inhabitants. Among other statistics, were included those of receipts and payments, assets and liabilities of municipal corporations, the assessed valuation of private property, and the rate of ad valorem taxation. With a few minor changes, these financial statistics of the Department of Labor were identical with those of the Eleventh Census in 1890. By an executive order issued under provision of the act creating the Department of Commerce and Labor, the compilation of these social statistics in 1902 was transferred to the Bureau of the Census. The statistics now being compiled by the Bureau are for the year 1902.

When the above transfer was made, Mr. Carroll D. Wright, Commissioner of Labor, recommended that thereafter these statistics be collected and published biennially instead of annually, but a bill providing for this failed to pass. The Secretary of Commerce and Labor, however, has directed that hereafter the social statistics of cities of 30,000 inhabitants or over shall be taken every two years. Under the practical working of this order the financial statistics of cities of this class, which will shortly be issued by the Bureau of the Census for 1902, will be omitted for 1903 and 1904, and the next to be collected will be those for 1905, which will be compiled in the closing portion of the year 1906.

The statistical report for 1902, will give nearly ten times as much data as any similar publication of the Census or Department of Labor. So far as practicable it will present comparative exhibits of municipal payments and receipts, classified in accordance with the general plan of the National Municipal League, thus making available to students of municipal statistics much hitherto inaccessible data. The greater volume of these statistics and the greater detail with which they are to be presented do not, however, necessarily making them more valuable, and may, in fact, tend to make them valueless and even misleading and dangerous unless the statistics themselves are fairly comparable.

The Eleventh Census and the Department of Labor both sought to use the printed municipal reports as the basis of statistics, but it found that they could not be so employed. The reasons why comparable statistics cannot be compiled from these reports are that the governments of the various cities do not have identical systems of organization; their accounts are differently classified; and they make use of widely diverse methods of accounting. Under these circumstances, an approximation to comparable statistics is obtainable in one manner only; by the employment of expert special agents who correct and supplement the data taken from printed reports by compilation from the books of original record.

The first difficulty met with is the preparation of a suitable schedule. To secure all the data relating to municipal finance which the members of the National Municipal League, the students of American municipal finance and the public officials of our large cities desire, called for a much more comprehensive schedule than any previously employed in the collection of such statistics. In attempting the preparation of such a schedule there has been a larger degree of success than those in charge of the work hoped for, and yet the results are far from perfect. A revised schedule and set of instructions have recently been drawn up and mark a great improvement as they embody the results of the experience of the special agents in the field and the study of the employees of the bureau engaged in compiling the data on the schedules. An examination of the books of original record kept by the average American city furnishes countless instances of great confusion. In the great majority of cities the agents of the Census have been obliged to scrutinize practically every entry of the published financial reports and trace them to the ledger accounts. Thus, in one of the larger cities our agent found an expenditure of $600 for a public celebration included in the printed report as capital outlay for sewer construction. There was no attempt at fraud or concealment, the misleading entry simply reflecting the want of a good classification whereby the costs of street repairs due to extra work caused by the celebration might be properly assigned.

But a critical examination in this way of the books of every large city requires a great expenditure of time and money. The government cannot afford to spend each year the large sums required, and if such statistics are to be compiled annually, there must be such changes in municipal accounting methods as will bring the expense down to a reasonable limit, and at the same time make these statistics more comparable and thus more valuable than at present. Two changes must be adopted by the cities: 1, a more uniform classification of accounts, and, 2, more uniform methods of accounting.

Cities should keep their books so as to show, (1) the honesty of the officials in charge of administration, and (2) the relative efficiency of that administration. As a rule, the books of all our great cities are kept in such a

*Abstract of a paper presented at the annual meeting of the National Municipal League, in Chicago, April 27, 29.

†Chief Statistician, Census Office, Washington, D. C.

manner that it is possible from an examination of the same to show whether there has been a defalcation or embezzlement. They are not, however, so kept at the present time as to meet the second of the above-mentioned requirements. This is because there is no uniformity in present methods of administration and accounting. Consequently, it is impossible to use the experience of one city as a test of the relative efficiency of the administration of another. Further, few cities keep their books in such a manner that they can critically check the cost of municipal work performed in one year with that performed in another and definitely ascertain the variation and the cause thereof.

We all want to demonstrate the relative efficiency and economy of various experimental movements in municipal affairs. We want information concerning the advisability of public ownership and operation of quasi-public enterprises and the per capita cost of the services furnished by these enterprises under given conditions. The forthcoming compilation of the census will furnish more information of trustworthy nature relating to these subjects than any similar publication even issued in this or any other country.

The municipal finance schedules and instructions, prepared by the Bureau of the Census, have played an important part during the last year in advancing this movement, having been made the basis of the schedule and instructions issued by the Secretary of State of New York for the collection of the financial data of cities of the second and third classes within that commonwealth. It is to be regretted, however, that the experience of the census could not have been utilized in their preparation. That experience has disclosed many weak spots and imperfections in the first schedules and the New York authorities would doubtless have realized much greater progress in the current year had the knowledge thereof possessed by the census been made use of. Ohio has recently adopted and put into operation a common classification of municipal accounts and a uniform system of municipal accounting.

Whatever the defects of the census schedules may be they cannot be charged to any lack of friendly interest or co-operation on the part of city officials. The difficulties that must be overcome before we can secure the adoption of uniform methods of accounting for all our large cities, and thus lay the foundation for truly comparable statistics, seem to me to be as follows: We must demonstrate beyond a doubt that it is possible to arrange a classification of municipal payments and receipts that shall be applicable to all cities. The census report on municipal finance will show something of the limitations within which the scheme of classification adopted by this league can be made the basis of a uniform system of accounts. I believe that scheme, with minor changes, can be made the basis of a common classification of accounts and hence of a uniform system of accounting for all our cities.

There is one question with reference to this subject which this League should carefully consider: How far can the annual collection and prompt publication of detailed statistics of the fiscal operations of our large cities, such as are called for by the census schedule, be made to contribute to the advancement of this cause? Individually, I believe the field and office work of preparing a second report along the lines of the one now being prepared for the decennial publication can be done at less than half the cost of the investigation just closed. This saving would, in part, be the natural result of experience and study on the part of the census employes, while to no small extent it would be due to the greater interest taken in the subject by city officials and their consequent co-operation. If the census can strengthen this latter factor by an annual publication such as that formerly issued by the Department of Labor, and a number of cities be led thereby to classify their accounts so closely in keeping with the census classification as to make it possible after a few years for the census to dispense with all field work for such cities, an immense service will have been rendered to our country. Such a result would mean also an ultimate saving in the collection and classification of municipal statistics.

A 50-TON STIFF LEG DERRICK.

The Pittsburg Railways Co., of Pittsburg, Pa., has establishd a new power house on Brunot's Island, which is served by a sidetrack on a timber trestle 63 ft. high, for the delivery of coal and supplies. All materials and supplies are handled by the steel stiff-leg derrick shown in the accompanying cut, except that coal is delivered by the chutes fitted between alternate pairs of the trestle bents. The trestle is parallel with the Ohio Connecting bridge between Pittsburg and Allegheny.

50-TON STEEL DERRICK AT THE POWER PLANT OF THE PITTSBURG RAILWAYS CO., PITTSBURG, PA.

American Hoist & Derrick Co., St. Paul, Minn., Builders.

The derrick is built up of structural steel, with all the important castings made of Tropenas steel. The mast and stiff legs are of box section, built up of plates and angles; the boom has chords and latticing of angles. The wire cables are of flexible plow steel, and all sheaves have bronze bushings, and are fitted with compression grease cups. The mast is 50 ft. high, with a bull wheel 16 ft. diameter for the swinging rope, the rim of the wheel being attached to inclined braces riveted to the mast. The boom is 100 ft. long, and its section at the middle is 2 ft. 2 ins. wide and 5 ft. 7 ins. deep. Concrete foundations are used for the hoisting plant and for the derrick, the foundation of the mast being 12 ft. deep, and the foundations of the stiff legs being 18 and 12 ft. deep.

The hoisting and slewing movements are effected by separate engines, both supplied with steam from a vertical boiler 4 ft. 2 ins. diameter and 8 ft. 5 ins. high, carrying 100 lbs. pressure, and rated at 50-HP. There is a double drum hoist, driven by a double cylinder horizontal engine with cylinders 10 × 12 ins. The drums are mounted, one in front of the other, on a heavy bed, and one is used for raising and lowering the load, while the other raises and lowers the boom. On the end of each drum shaft is a winch head. The swinging engine has a single drum, operated by a pair of horizontal cylinders 4¾ × 6 ins. This plant is enclosed in an engine house, with glass sides, but the front is hinged at the bottom and lowered by block and tackle when the derrick is to be operated, so that the engineman can have a full view of the work. All the operating levers and wheels are conveniently grouped behind the rear drum.

The derrick can hoist its maximum load of 50 tons at a speed of 10 ft. per minute, or lighter loads at 30 ft. per minute, the maximum capacity being 50 tons at 50 ft. radius. It will swing over an angle of 270°, but not more than 180° with its maximum load; the boom can be lowered to a horizontal position, giving an effective radius of 100 ft.

Mr. F. Uhlenhaut, Jr., is Chief Engineer of the Pittsburg Railways Co., and the derrick was built and installed, with its machinery, by the American Hoist & Derrick Co., of St. Paul, Minn.

TEST TO DESTRUCTION OF A 65-FT. TRUSS BRIDGE SPAN OF REINFORCED CONCRETE.

The remarkable results obtained by Mr. Considère from compressive tests of hooped concrete columns, are probably familiar to many of the readers of Engineering News. Briefly stated, however, this prominent French investigator found by test that a column reinforced by a circumferential helix of steel would support without rupture a load several times greater than would a column of the same dimensions reinforced in any other way. In view of the high compressive strength developed by hooped concrete columns, the possibility of using members so reinforced for arch ribs and for compression chords in braced girders of long span, seemed worthy of investigation, and in 1903, Mr. Considère undertook such a study by building a truss span 65 ft. long, with chords of hooped concrete, and testing it to destruction under gradually applied load. The results of this study have been published in full in "Annales des Ponts et Chaussées" for the third quarter of 1903, and we abstract the more important in the following paragraphs:

DESCRIPTION OF TEST STRUCTURE.

The drawings of Fig. 1 show a part elevation and a cross-section of the test structure. As will be seen, it was composed of two girders spaced 2.5 m. (8.2 ft.) apart and braced together by a slab and beam floor, and by lateral bracing in the plane of the top chord. Each girder or truss was composed of a parabolic top chord of 20 m. (65.6 ft.) span and 2.3 m. (7.54 ft.) rise. The bottom chord was straight and connected the ends of the top chord. The web system consisted of verticals and diagonals, which divided the truss into panels 1.54 m. (5.05 ft) long. The construction of the several members in detail was as follows:

The top chord was constructed with a center panel of reduced section and was of octagonal cross-section throughout. All panels except the one of the center had a uniform sectional diameter of 25 cm. (9.84 ins.) and were reinforced by a helix 20 cm. (7.87 ins.) in diameter of 9.53 m. (0.376 in.) wire coiled to a mean pitch of 31 mm. (1.22 ins.), and by eight longitudinal bars 11 mm. (0.43 in.) in diameter inclosed within the helix or hooping. In the reduced section of the center panel the diameter of the concrete octagon was made 20 cm. (7.87 ins.) and the reinforcement consisted of a helix 16 cm. (6.29 ins.) in diameter of 10.9 mm. (0.428 in.) wire coiled to a mean pitch of 24 mm. (0.94 in.); the longitudinal bars were the same as in the other panels. As will be seen, the reduced panel section had a smaller sectional area of concrete and a larger amount of metal

than the normal panel sections. Another point to be noted is the sub-vertical which was inserted to support the entire panel chord at the middle.

The cross-section of the bottom chord was nominally octagonal, like that of the top chord. It was reinforced by 37 longitudinal bars of 13.3 mm. (0.523 in.) diameter, which, at the ends of the span, passed through steel shoes and were there threaded and provided with nuts. This bundle of 37 bars was spirally wound with 4 mm.

Fig. 1. Diagram Elevation and Cross-Section of Concrete-Steel Truss Span Tested to Destruction.

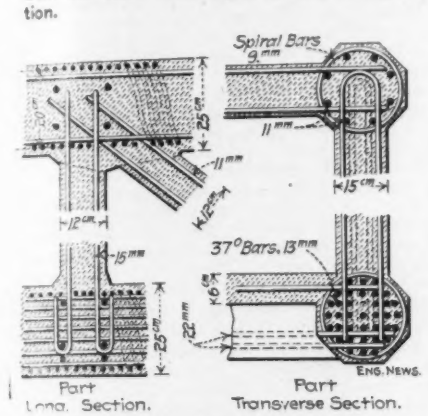


Fig. 2. Details of Reinforcement for Concrete-Steel Truss Span.

(0.16 in.) were spaced quite closely at the panel points and further apart at the center of the panel. The diameter of the bottom chord was 25 cm. (9.84 ins.).

The posts and diagonals forming the web system were all rectangular in section and each was reinforced by four round bars, one at each corner. These bars were 15 mm. (0.59 in.) in diameter for the posts and 11 mm. (0.43 in.) in diameter for the diagonals. The web member reinforcement was designed to loop around the chord reinforcement, and that of the floor beams as shown by the sections of Fig. 2, but through an error this construction was not actually carried out; separate bars were used with bent ends which penetrated varying distances into the chord members and often had only a slight penetration. The members of the top lateral bracing were constructed substantially like the web members. The floor construction consists of a slab 6 cm. (2.36 ins.) thick with transverse ribs or beams at each panel point; its construction is clearly shown in Fig. 2.

Only one feature in the erection of the reinforcement calls for special mention. Owing to the thick spacing of the bars in the tension chord, it was desirable that they should be tautly alined in the direction of the tensile stress; otherwise there would be danger of rupturing the thin envelope of concrete when the rods tightened under load. The metal employed for reinforcement was soft steel having an ultimate strength of about 26 tons per square in. The concrete for the hooped members was composed of 800 kgs. of Portland cement to 400 liters of sand and 800 liters of gravel passing a screen of from 12 to 15 mm. (0.47 to 0.59 in.) mesh. For the web members and laterals the proportion of cement was reduced to 600 kgs., and for the floor it was reduced to 300 kgs. Altogether about 13.5 cu. yds. of concrete were used in building the span.

DESCRIPTION AND RESULTS OF TESTS.

The construction of the test span was completed on July 28, 1903, and it was tested on Nov. 11 to 13, 1903, in the presence of the Commission du Beton Armé" of France, and a number of invited engineers. A load of 34 metric tons composed of railway rails was at first placed on one half of the span in such a manner as to submit the diagonal members to a tensile stress of about 1,000 kgs. per sq. cm. (14,223 lbs., per sq. in.); examination of the connections revealed no damage whatever. The load was then distributed uniformly and increased to 60 metric tons. Including the dead load, 25 metric tons, this load brought a compressive stress of 90 kgs. per sq. cm. (1,280 lbs. per sq. in.) on the normal top chord section, and of 150 kgs. per sq. cm. (2,133 lbs. per sq. in.) on the reduced top chord section. No sign of harmful strain was visible under this loading. The deflection at the center of the span was about 10 mm. (0.39 in.). The continued loading of the bridge caused no damage and furnished no other notable feature until the imposed load reached 180 metric tons. Under this load, which brought a stress of 215 kgs. per sq. cm. (3,058 lbs. per sq. in.) on the normal top chord section and a stress of 353 kgs. per sq. cm. (5,049 lbs. per sq. in.) on the reduced top chord section, there appeared simultaneously at several points signs of rupture. About a third of the span from the abutments there appeared several hair line cracks in the bottom chord, and at three panel points, two in the south truss and one in the north truss, near the center of the span, the surface of the concrete of the top chord exhibited a diagonal crack about as shown by Fig. 3. These cracks were accentuated as the load was increased, and when it reached 200 metric tons the concrete cracked off the hooping in the reduced top chord section and left the metal bare. At this time the compressive stress on the hooped core of concrete remaining was 608 kgs. per sq. cm. (8,640 lbs. per sq. in.). The same phenomena were exhibited at various points of the normal top chord section as the load was increased from 220 to 240 metric tons. Under the 240-ton load the stress on the hooped section was 460 kgs. per sq. cm. (6,542 lbs. per sq. in.).

Complete failure was produced by a load of 241 metric tons, which brought a compression of 720 kgs. per sq. cm. (10,240 lbs. per sq. in.) on the hooped section of the top chord. The failure occurred at panel point I (Fig. 1) in the top chord of the north truss, and consisted first in the bursting outward of several wires of the helix and second of the shearing of the concrete on a diagonal plane. This movement caused the rupture of the top chord of the same truss in the two end panels. The character of this record break is quite clearly shown by Fig. 4. The bottom chords of the truss, despite the remarkable deflection shown by the engraving, exhibited only slight fissures. The posts and diagonals of the panels adjacent to the rupture in the top chord were completely shattered, as is indicated by Fig. 4. Except at the breaks noted, the top chord was nowhere cracked and the concrete covering of the hoops was in most places intact. The reduced section of top chord showed no further injury than that already noted.

In view of these facts, Mr. Considère is disposed to lay the cause of failure under the load of 241 tons to faulty construction of the connection at panel point I. At this panel point the bars reinforcing the post, or vertical web member, extended into the top chord only to a little inside the hooping and they, therefore, it is thought brought a direct pull on the adjacent hoops which caused them to burst. Leaving this fact out of consideration, however, Mr. Considère expresses the belief that the results of the test exhibit the value of hooped concrete in a very favorable light and warrant its consideration in designing structures for which engineers have not heretofore regarded reinforced concrete as at all permissible.

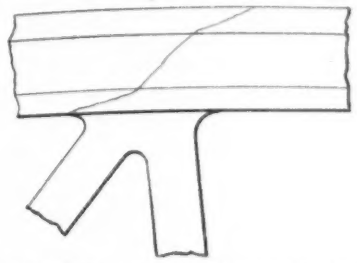


Fig. 3. Diagram Showing Position of Cracks in Top Chord of Concrete-Steel Truss Under Uniform Load of 180 Metric Tons.

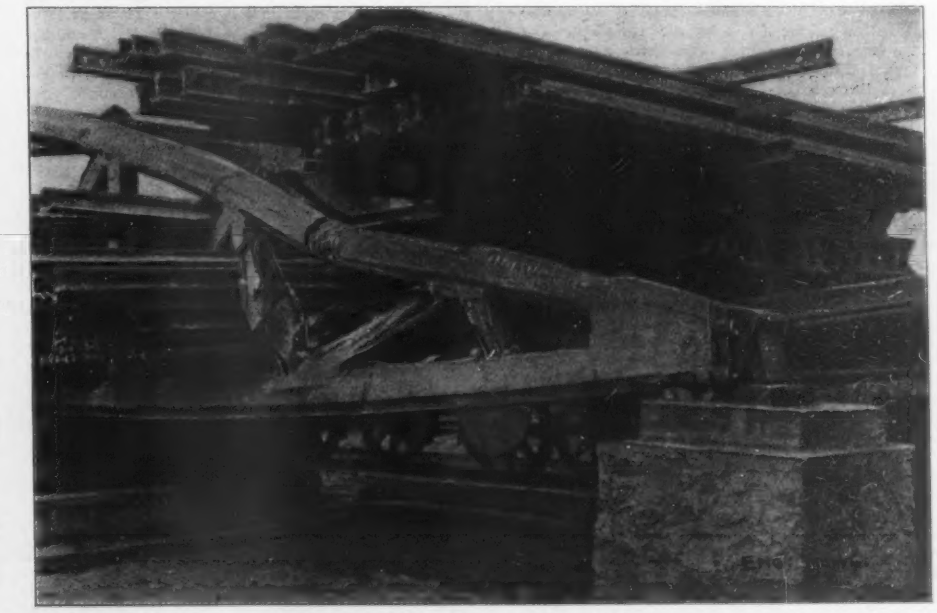


FIG. 4. VIEW SHOWING SECONDARY RUPTURE AND DEFLECTION OF BOTTOM CHORD UNDER BREAKING LOAD OF 241 METRIC TONS.

SOME FEATURES OF THE MODERN LOCOMOTIVE.*

By W. F. M. Goss,† M. Am. Soc. M. E.

LIMIT OF POWER.—By the process which goes on within the firebox of the modern locomotive, each pound of coal burned will, under favorable conditions, sustain one indicated horse-power for a period of from 12 to 15 minutes. At the speed of ten miles an hour it will serve to carry six tons of freight one mile. Within certain limits, the power developed is nearly proportional to the amount of coal burned.

In the development of the modern locomotive, grates have been enlarged and heating surface extended that larger amounts of fuel may be burned. In one direction only has the designer found the way blocked against his ingenuity. He has not been able materially to augment the strength of the fireman, and consequently when running under constant conditions, the power of the locomotive has not increased in proportion to its dimensions. A laborer is working at a fair rate when, in unloading coal from a gondola car, merely dropping it over the side, he handles 6,000 lbs. of coal per hour. *At the limit*, a locomotive fireman will handle an equal amount, standing on an unsteady platform, placing it upon some particular part of the grate, and usually closing the door after each

*Extract from an address delivered before the American Society of Mechanical Engineers at New York, April 26, 1904.

†Dean, Schools of Engineering of Purdue University, Lafayette, Ind.

scoopful. This rate will serve to develop approximately 1,200 I. HP. This rate cannot be exceeded under sustained conditions of running, though for short intervals the rate of power may outrun the rate of firing. Because of the limitations upon the strength of the fireman, it is probable that further growth in locomotives will await the coming of an automatic stoker, which will remove its operation from dependence upon the physical condition of a single man.

LIMIT OF DRAW-BAR PULL.—The amount that a locomotive will pull at the draw-bar depends upon its speed. At slow speed, the maximum pull is limited by adhesion. After the point in the speed is reached for which the adhesion is sufficient to permit the development of the full power, the pull, assuming no loss of power between cylinder and draw-bar, is inversely proportional to the speed.* For a locomotive capable of developing 1,200 HP., the pull at a speed of 25 miles per hour is 22,500 lbs., while at 80 miles per hour, the pull is 7,000 lbs. At 80 miles, the loss between the cylinder and draw-bar reduces the pull to about 5,000 lbs.

BOILER MODIFICATIONS.—The discussion of grate areas and fireboxes naturally suggests the question as to whether there are not other forms of boilers than those in common use which would better serve the purposes of a locomotive. The Vanderbilt boiler, which has a cylindrical firebox, is to be regarded as one answer to that question. Again, the extensive adoption of water-tube boilers in stationary and in marine service leads naturally to speculation concerning the application of this type to locomotive practice. Indeed, designs of water-tube locomotive boilers are not wanting. Among several that have been proposed is that of Mr. Drummond, of the London & South-Western Railroad, the important feature of which is a single large flue across which water tubes are extended. While the boiler thus formed is technically a water-tube boiler, it is practically a shell boiler having an unusual arrangement of tubes.†

In considering the possible success of any water-tube boiler, it will be well to remember that the present locomotive boiler is not much heavier than the best of the (stationary or marine) water-tube boilers of similar capacity, and the fact that the boiler-shell is depended upon to serve as a part of the frame work of a locomotive makes it impracticable to abandon the present shell without greatly increasing the weight of the frames. The side frames are tied to the boiler at frequent intervals, and such important details as guide yokes are in many cases as much dependent upon the boilers for their support as upon the frames. All this increases the difficulty of applying a water-tube boiler to the locomotive.

THE FRONT END.—Closely identified with the problem of boiler design is that of front-end arrangement. The front end includes the extended shell of the boiler forming the smokebox, and in general all mechanism therein contained, such as steam and exhaust pipes, nettings, diaphragms, and draft pipes; it also includes the stack. The office of the front end is to draw atmospheric air into the ashpan, thence through the grate and fire; to draw the furnace gases through the tube of the boiler, thence under the diaphragm and into the stack, and to force them out into the atmosphere. In order that this movement may take place, a pressure less than that of the atmosphere is maintained in the smokebox so that when the locomotive is working, there is a constant flow from the atmosphere along the course named and back to the atmosphere again. The difference in pressure between the atmosphere and the smokebox is spoken of as the draft, and, under normal conditions of running, is usually represented by from 4 to 6 ins. of water. The draft thus expressed, however, is approximately three times greater than that to which the fire is actually subjected. Thus, a third of the total draft is required to overcome the resistance of the ashpan and grate together with the fire thereon. Another third is required to overcome the resistance of the tubes, and another third to overcome the resistance of the diaphragm.

In the design of the front-end, practice has wabbled badly. The front-end was at first quite short, surmounted by a diamond stack, containing the netting. It was then extended to constitute a cinder trap. Locomotive builders afterwards discovered that to use the front-end as a cinder-trap is unnecessary and undesirable, and it is now in the process of being shortened again that it may not hold cinders, but may become entirely self-cleaning. While this portion of the locomotive has been the subject of a considerable amount of patient study, and while great progress has been made, much yet remains to be done before the whole problem of the front-end is completely solved.

THE ENGINE.—Passing now from the boiler to the machinery, mention must first be made of the recent and very general substitution of steel for iron in all cast parts. Such castings as wheel centers, axle boxes and rocker boxes, which were formerly of iron, are now cast in steel, with the result that the engine machinery has been lightened, and the weight thus saved has been added to the boiler.

*See a fuller discussion of this subject, with illustrative diagrams, in "Some Factors Affecting the Power of Locomotives," by the same author, in Eng. News, March 6, 1902.

†A shell-boiler with water-tube firebox was described in Eng. News, Oct. 1, 1903.

The form of each individual part of the machine has been carefully studied with reference to the service it is to perform. For example, in an attempt to diminish wear and to reduce the chance of failure in valve gear, the width of links and the length of rocker and saddle pins, have been made to occupy the full width between the frames of the engine. Piston valves with their superior balance have largely superseded flat valves. By the use of wheels of larger diameter, and reciprocating parts of better design, the problem of counterbalancing driver-wheels has been so simplified that extremely bad work in counterbalancing is now rarely found, except perchance in combinations which are patented.

I am often asked why it is that so much difference exists in the valve gears of American and foreign locomotives. First of all, it is but proper to note that whenever a practice becomes settled, there is somewhere a reason for it. The Stephenson link-motion has generally been used in this country because it is a good device, and because it is easily worked into the general lines of the American locomotive. In English practice, where inside cylinders are common, that portion of the main axle which lies between the frame is largely occupied by the cranks. There is no room for four eccentrics, and consequently the Joy gear (which takes its motion from the connecting rod) is much used. This gear seems on the whole admirably adapted to the condition described, though English designers complain that by its use the motion of the valve is considerably disturbed by a low joint or other irregularity in the grade of the track. Other gears are used in England, though none perhaps to the same extent or with as good reason as the one referred to. The Germans make very general use of the Walschaert gear which takes its motion from a single eccentric and the cross-head of the engine. The French designer may choose any of the types mentioned, or, if occasion seems to demand, may produce an original gear. The choice of a gear is in most cases doubtless made from practical considerations rather than from theoretical. In working out the general lines of the design of a locomotive, one or another form adapts itself to the purpose better than others. Of course, this is not true in all cases, but assuming the choice of gear to be controlled by proper limits, it might be so, for it is not a difficult thing to secure a distribution of steam within a locomotive cylinder which will give results approaching maximum performance.

A chief requisite in any valve gear is a degree of stiffness, and an absence of lost motion which will make the movement of the valve positive. These qualities are especially necessary in the gear of a locomotive, for in this type of engine, the port opening at running cut-off is frequently not over ¼ or ⅜-in., so that even a slight defect in any of the mechanism between eccentrics and valve produces large proportional effects upon the time and extent of the port opening. Ten years ago, light and poorly designed gear was a common defect in the American locomotive. Then it sometimes happened that the steam distribution depended quite as much upon the oil-can as upon the position of the reverse lever, and reports are current of an engine which would run well under a partially open throttle, but would stop if the throttle were fully opened, the mechanism being insufficient to move the valve when the pressure was heavy upon it. But the valve gear of the modern locomotive is not of this sort. With its heavy and direct connection, its double suspended link, and with the light weight of the valve to be moved, a marvelously good steam distribution is secured even at the highest speeds. Those who, seeing but one side of the really complicated problem, believe that locomotive valve gears ought to be revolutionized, should investigate carefully before they proceed. They should remember that the modern locomotive under ordinary conditions of running, rarely requires more than 32 lbs. of steam per I. HP., while under favorable conditions it requires less than 25 lbs. Few simple stationary engines exhausting into the atmosphere, with their more complex forms of valve gears, are doing any better than this, which is evidence of the narrowness of the margin limiting possible improvements in this direction.

STEAM PRESSURE.—With constant improvements in methods of boiler construction and in the design of machinery there has been a steady increase in steam pressure. The range has been from 130 lbs. in 1880, to above 200 lbs. in 1900. This increase in steam pressure is responsible for many changes in the details of locomotives. Boilers have, of course, become heavier, and where power has not increased, cylinders have become smaller and lighter. In other words, by virtue of the higher steam pressure, the dimensions of the engines of the locomotive have not increased in proportion to their increase in power. The higher steam pressures are chiefly responsible for a very general adoption of the piston valve. The extent to which they have affected the economy of the engines cannot be definitely stated. From a purely thermodynamic point of view, each increment in pressure should bring its return in increased economy, but as the scale of pressure ascends, the economy increment diminishes, while radiation and leakage losses increase. The range of pressure now common in locomotive service is so high, as compared with that employed in other types of engine, as to fairly raise the question whether economical limits have not already been reached or even exceeded. The practical question can best be expressed somewhat as follows: Suppose an opportunity is presented whereby the boiler of a proposed locomotive may be 5,000 lbs. heavier than that of an existing class; should this additional weight be utilized in making a stronger boiler that a higher pressure may be carried, or should it be utilized in making a larger boiler that the rate of evaporation may be reduced? Either course should result in increased economy in operation, but which course will prove most economical and where the limits lie, cannot be stated.

COMPOUNDING.—With steam pressures up to simple engines approaching 200 lbs, the advisability of using compound cylinders began to be considered. In the early nineties the compound locomotive became a subject of much interest in this country. The advantage of compounds as an abstract proposition was not disputed. The problem was to build up a mechanism which, while meeting the requirements of correct theory, would at the same time be sufficiently strong and simple to justify its use under the severe conditions of locomotive service. At first, all efforts were directed to the development of a two-cylinder type, the impression being that to succeed a compound must have no more parts than a simple engine. But as time passed and as all locomotives grew in size, the problem of the two-cylinder compound became one of increasing difficulty, until now the clearance in tunnels and past station platforms is on many roads insufficient to allow passage of the large low-pressure cylinder. Meanwhile, the Vauclain four-cylinder type has come into extensive use, and four-cylinder tandem-compounds are being introduced so that now the tendency is strongly toward a four-cylinder type. In all this, there has necessarily been much experimentation, and experimentation sometimes leads to troubles and disappointments as well as to promise and success. In some cases the compound locomotive has proven expensive to maintain, in others ill-adapted to the service expected of it.

Compounds should not often be used under conditions requiring frequent starting and stopping, or where changes in the grade of the track are such as to require frequent changes in the conditions of running. It is on the long, steady pulls that they will show their largest gains in efficiency over the simple engine. Another fact of great importance in any discussion of the economic performance of the compound as compared with the simple, and yet one which is rarely taken into account, is that which concerns the proportion of the total coal used, which is burned while the engine is advancing its train over the road. In the freight service of the average road not more than 80% of the total coal burned is effective in the generation of steam for the cylinder of the engine. The other 20% represents fuel used in firing up, in keeping the engine warm while standing, or remains in the firebox at the conclusion of the run. Obviously, no change in cylinder arrangement can reduce the amount of coal thus consumed. A compound locomotive, therefore, which upon test shows a fuel saving of 10% over that required by a simple engine, will when put into regular freight service, have a chance to save but 10% of 80% of the amount of coal which the simple engine uses. These are facts which should be fairly faced in any discussion of the compound problem. They in no wise discredit the usefulness of compounds, which without doubt are to have a large part in the future service upon American roads.

It will be of interest to consider a design which theoretically at least must be regarded as the highest development of that type. I refer to the design of the de Glehn balanced compound which was first brought out in 1886, and which for several years has been the standard for all new passenger power on several of the larger roads of France. The fact that the Pennsylvania Railroad Co. is at great cost importing from France an engine of this type for experimental work on its lines; that the American Locomotive Co. is building a large engine upon this general design, and that both of these will be tested upon the locomotive testing plant of the Pennsylvania Railroad Co. at St. Louis this summer, should give additional interest to the de Glehn balanced compound.

In the de Glehn design, the two low-pressure cylinders are placed side by side between the frames and connect with inside cranks, which are set quartering on the forward driving axle. The details of these cylinders and surrounding parts are similar in every respect to those of all inside-connected engines. Thus placed the low-pressure cylinders are well protected from radiation, and they connect to the stack with exhaust passages which are both short and direct. The high-pressure cylinders are placed outside the frame and connect with outside cranks in the wheels of the second driving axle. These cylinders are not in the same cross-section with the low-pressure cylinders, but are carried back on the frames a distance which is substantially equal to the spacing of the driving axles, so that the main rod of the outside cylinder connecting with the second driving axle is of the same length as the main rod of the inside cylinder connecting with the first driving axle.

The two or more pairs of driving wheels are connected by coupling rods, the several cranks being so arranged that the pins for the coupling rods in the front drivers are set diametrically opposite the inside cranks of the axles carried by these wheels. When one of the outside pistons

FIG. 1. THE MAHONING IRON M

FIG. 2. THE FAYAL IRON MINE AT EVELETH, MINNESOTA.

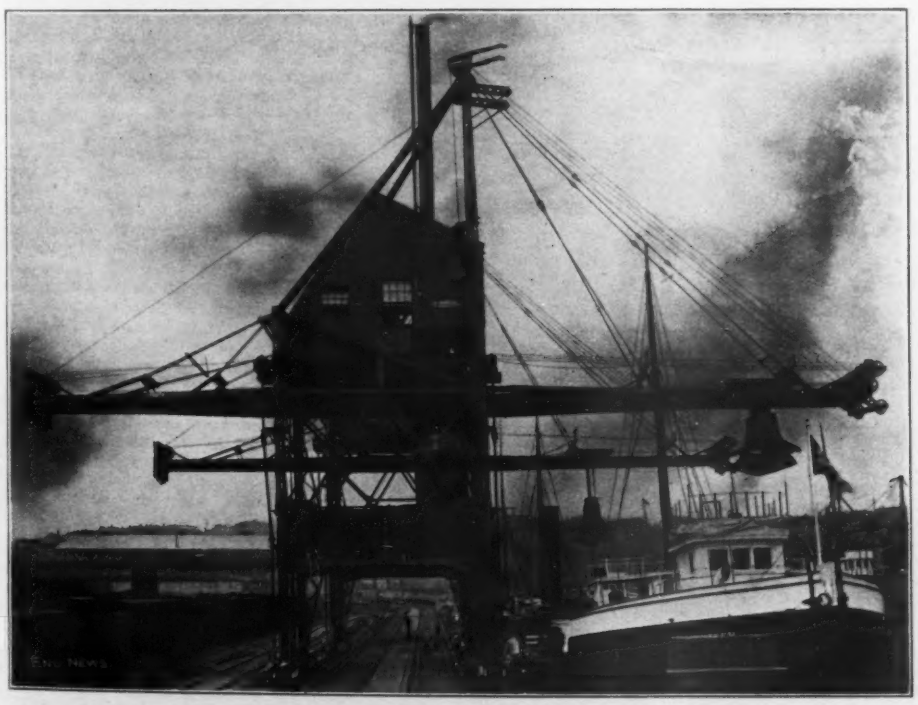


FIG. 5. DIRECT UNLOADER FOR THE FAST PLANT OF THE CLEVELAND FURNACE COMPANY, CLEVELAND, OHIO.

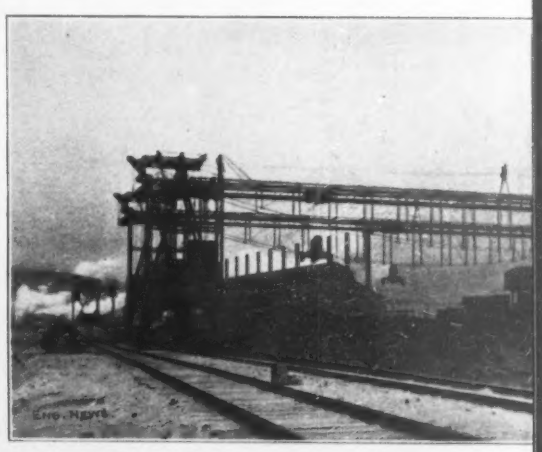
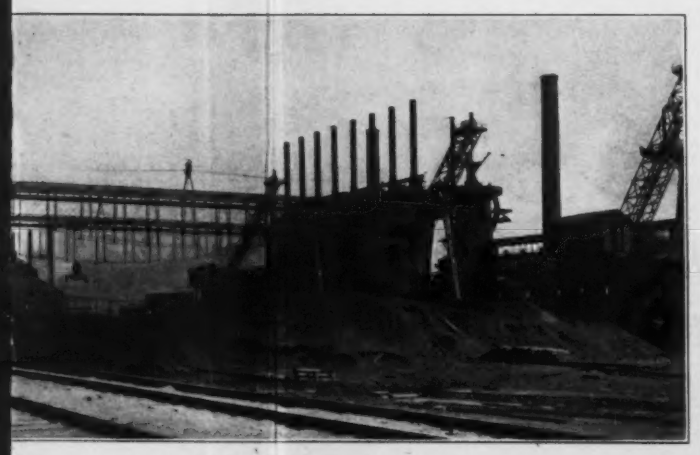


FIG. 11. YARD PLANT F
CARNEGIE STEEL COMPANY,

SOME MODERN
EXCAVATING AND HA

E MAHONING IRON MINE AT HIBBING, MINNESOTA.

FIG. 3. THE DULUTH, MARQUETTE & NORTHERN R. R. IRON ORE DOCKS AT DULUTH



11. YARD PLANT FOR HANDLING ORE,
E STEEL COMPANY, RANKIN, PENNSYLVANIA.

OME MODERN PLANTS FOR
ATING AND HANDLING IRON ORE.

FIG. 12. YARD PLANT FOR HANDLING ORE
CRUCIBLE STEEL COMPANY, CLAIRTON, PENNSYL

OCKS AT DULUTH, MINNESOTA.

HANDLING ORE,
RTON, PENNSYLVANIA.

moves forward, an inside piston moves backward, the reciprocating parts of each high-pressure cylinder being balanced by the reciprocating parts of its neighboring low-pressure cylinder. If, under these conditions, each wheel is perfectly balanced for its revolving parts, and if the reciprocating parts of the high-pressure engine have the same weight with those of the low-pressure engine, the machine as a whole will be balanced, both horizontally and vertically. So far as the action upon the track is concerned the balance will be practically perfect.

It will be seen that the machinery of these engines, as compared with that of an American two-cylinder engine, involves nearly double the number of parts. Thus, the French engine may have the same number of axles and wheels, but all other machine parts such as pistons, cross-heads, main rods, valve motions and valves are in duplicate. Each cylinder is treated as a complete unit, having its individual cross-head and its individual main-rod. There are four sets of cross-heads instead of two, as in American practice, and four main-rods instead of two. But these apparent disadvantages are more than compensated for by the increased lightness of the parts involved, and by the possibility of a higher character of design. In American practice, the two main-rods of a modern engine must each be designed to transmit from 800 to 1,000 HP. That this may be accomplished, rods have become enormously heavy, and crank-pins have grown to be as large as axles were ten years ago. Moreover, the forces to be transmitted often exceed the ability of the fixed portions of the machine to withstand properly, hence, parts strain, journals and brasses fit badly, and hot pins and boxes result. If designed after the de Glehn type, it would have four light rods, each transmitting from 400 to 500 HP., and the pins would be much smaller. In such a case, who shall say that the duplication of parts when offset by such obvious advantages, increases the chances of failure? Is it not conceivable that under the conditions which have been described a larger number of parts may even involve fewer chances of failure?

Another objection often regarded as insurmountable by the American designer is that the inside cylinders necessarily connect inside of the frames, and, hence, a crank-axle is necessary. When this objection is analyzed, it is found to be based in part upon the extra cost of a crank-axle, and in part upon experiences of long ago. Early American engines which were fitted with crank-axles were very flexible, and were frequently run over exceedingly rough track. The record shows that in such engines there were numerous failures of axles. We therefore said, and for years have continued to say, that we will not use the crank-axle. Our modern engine, however, is less flexible than the earlier one, and is less subject to strains through inequalities in the track. Our advantages in this respect are at least equal to those of other countries. If England and France can run crank-axles, why may we not do the same? The fact that these countries do use them, and meet with few failures, would indicate that the American objection is largely historic. Moreover, the total power of the engine, instead of being transmitted through a single axle, as in American practice, is divided between two. The inside cylinders connect with the forward axle, and the outside cylinders with the rear axle. By the adoption of the de Glehn type, no single axle of our modern engines would be called upon to transmit as much as 1,000 HP., and present axle-diameters could be materially reduced, and at the same time allow a wider margin of safety. The balanced-compound, therefore, instead of introducing axle troubles, may reasonably be expected to lead to a betterment in present conditions. The advantages of the French type may be summarized as follows: It solves completely the difficult problem of balancing drive-wheels, it constitutes a satisfactory system of compound cylinders, it avoids the concentration of stresses in frames, it divides the total work of the cylinders between two axles instead of concentrating it in one, and the dimensions of the details of its machinery are such as will permit them to be well designed.

SUPERHEATING.—Quite recently there has appeared a rival to the compound in the form of a simple engine using superheated steam. While Americans have been rigidly orthodox in their application of principles, contenting themselves with such progress as may appear in the better design of machine parts and in the choice of better materials from which to construct them, and while the French have been busying themselves with the problem of their balanced compounds, German designers have been experimenting with superheated steam. There are now four or five locomotives (of the Schmidt superheater type) in service on the State Railroads of Prussia, and it is claimed that their performance is 25% better than that of similar engines using saturated steam.

The system there used involves no material changes in the exterior form of the locomotive boiler, but the tubing is modified, and the smoke-box design is so changed as to accommodate the superheater which is located therein. A flue 10 or 12 ins. in diameter extends from fire-box to smoke-box along the lower portion of the barrel of the boiler. This displaces from 20 to 30 of the small tubes which would otherwise have its place. Its purpose is to deliver to the smoke-box a considerable volume of furnace gases at a high temperature. To give room for the superheater, the diameter of the smoke-box shell is somewhat greater than the barrel of the boiler. The details of the design provide that, when the blower is on, dampers are closed which prevent the circulation of gases in the superheater, so that it is only when the throttle is open that the superheater does work. This would seem to make impossible any overheating of the superheater. In view of the favorable character of the operating conditions of the locomotive, it is likely that it will be found easier to maintain a superheater of this design on a locomotive than in connection with any other type of engine, and, moreover, that the superheating in locomotive service may be a pronounced success, while in other classes of service its future is still problematical. I would add that it is expected that two superheating locomotives of German manufacture are to be tested at St. Louis during the coming summer by the Pennsylvania Railroad Company.

MODERN METHODS OF HANDLING IRON ORE FROM MINNESOTA MINES TO PITTSBURG FURNACES.

By Charles H. Wright, M. Am. Soc. C. E.*

(With two-page plate.)

A journey beginning at the mines on the northwestern shores of Lake Superior and following the course taken by the cargoes of ore through the lakes to the harbors on the southern shore of Lake Erie, and then to Pittsburg to see how the raw-material passes through the final stages of its trip to the furnace stacks is one fruitful in objects of interest to the engineer. Each year from 20,000,000 to 25,000,000 tons of ore are taken from the Lake Superior mines, and since 1885 there have been taken out 225,000,000 tons. All this vast tonnage has to be loaded at the mines, transshipped to vessels at Lake Superior ports, transferred from vessels to cars at Lake Erie harbors, and unloaded at the Ohio and Pennsylvania mills, where it is smelted and wrought into the iron and steel of commerce. To perform these tasks machinery and methods of transportation have been developed which are among the most marvelous products of engineering skill, and they may all be seen in a trip of scarcely two weeks' duration from mines to furnace.

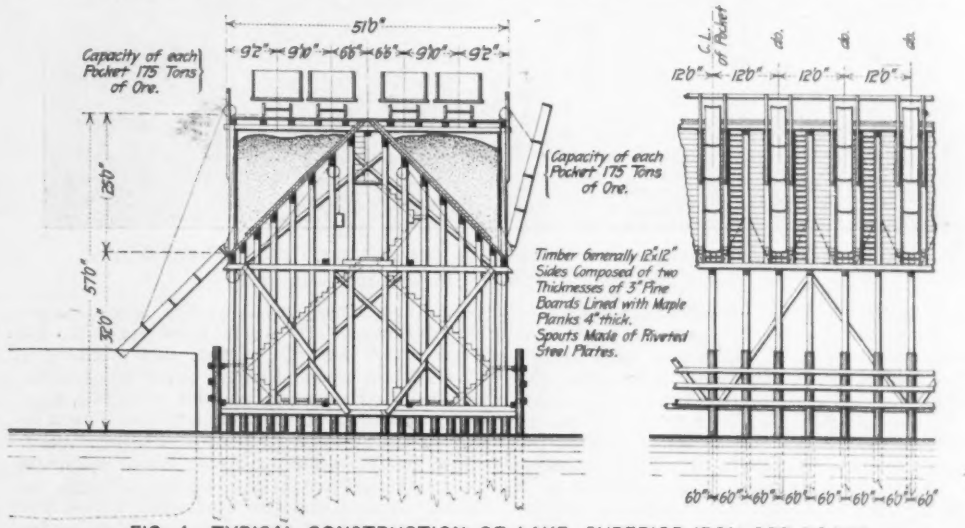


FIG. 4. TYPICAL CONSTRUCTION OF LAKE SUPERIOR IRON ORE DOCKS.

(Timber generally, 12 × 12 ins.; sides of two thicknesses of 3-in. pine boards lined with maple planks 4 ins. thick; spouts of riveted steel plates.)

In view of these facts, it is somewhat curious that the number of engineers and managers of manufacturing establishments in Europe, who come to this country to inspect the steel works and blast furnaces of Pittsburg, and, afterwards, to visit the ore-handling plants of the Lake Erie harbors, seems greater in proportion than the number of American engineers who make these trips. Why this is so is hard to explain, except on the general theory that things and places near at hand can be visited at any time, and the propitious time never comes to many. As an indication of the interesting engineering works which are open to observation, and to encourage engineers to take advantage of their opportunities to inspect them, the accompanying illustrations have been chosen and are briefly described. It is hoped also that the engravings and text may prove of technical value to those who are interested in modern methods of handling iron ore as they are practiced on the Great Lakes.

To proceed in logical order with his observations the visitor should start with a study of the mines themselves. The majority of these mines lie within 100 miles of the shore of Lake Superior, and are easily reached from Duluth. They are of two classes, which may be defined as surface mines and deep mines. Where the ore lies near the surface, the earth and rock covering is first removed and the ore then taken out by steam shovels, which load directly into railway cars. The views, Figs. 1 and 2, show the appearance of two of the most famous of the open-cut mines. When the ore lies at such a depth that the removal of the cover would be too expensive, the ore is reached by shafts and tunnels.

In deep mining the ore is sometimes taken out in layers, beginning at the top of the deposit and working downward, and sometimes the first slice is taken out at a considerable depth, timbering being used in both cases to support the roof material above, except in a few of the harder ores, which are self-supporting. Where the excavating begins at the top and is worked downward, shafts are carried down to a depth of 60 or 70 ft. and tunnels run from these shafts to the skip hoist shaft. The lower ends of the shafts are stopped by timber framing, in which valves or gates are built. The ore is dumped down the shafts and drawn off through the valves into the small cars, which take it to the skip hoist shaft, and it is hoisted in the skips to the surface, where it is again dumped through chutes into cars which run it out on tracks supported on trestle work, and dump it into piles around the trestle. Steam shovels then pick it up and load into railway cars When the ore has been removed, the timber supports are blasted down and the earth above allowed to settle, no attempt being made to save the timber. The ground surface over an excavated mine has the appearance of having been shaken by an earthquake. Tracts acres in extent can be seen where the surface has settled from 10 to 50 ft. or more.

Most of the cars used in conveying the ore from the mines to the lake ports are of special bottom dump type, requiring a minimum amount of labor in discharging their contents. When the cars reach the docks, they are run out on huge wooden trestles and the ore dumped into the bins built on these trestles. Some of these storage bins are about 2,000 ft. in length, and the docks of one railway at Duluth have a capacity of about 175,000 tons. The bins are divided into pockets of about 170 tons each.

From these bins the ore is drawn off direct into boats. A load of 7,700 tons has been put in a boat in about 2½ hours, and often 50,000 tons of ore are handled at these docks in a single day. At present these huge structures are built of timber. It seems probable, however, that steel must soon replace wood in this class of work. The danger of fire must be a constant argument against the timber construction. Figs. 3 and 4 show ore docks at Duluth.

Part of the ore shipped from the head of the lakes goes to Chicago, but the greater part is un-

*Chief Engineer, Brown Hoisting Machinery Co., Cleveland, Ohio.

loaded at some port on Lake Erie between Toledo and Buffalo. Toledo, Lorain, Cleveland, Ashtabula, Conneaut and Buffalo all have docks equipped with expensive special machinery built to handle ore and coal. Boats of 6,000 to 7,000 tons capacity are unloaded in from eight to fifteen hours, and the time is steadily being reduced. The next few years promise to show a great advance in a class of machines which are already producing remarkable results.

Fig. 5 shows a common type of modern machine called a direct unloader, this name coming from the fact that the machine handles the ore

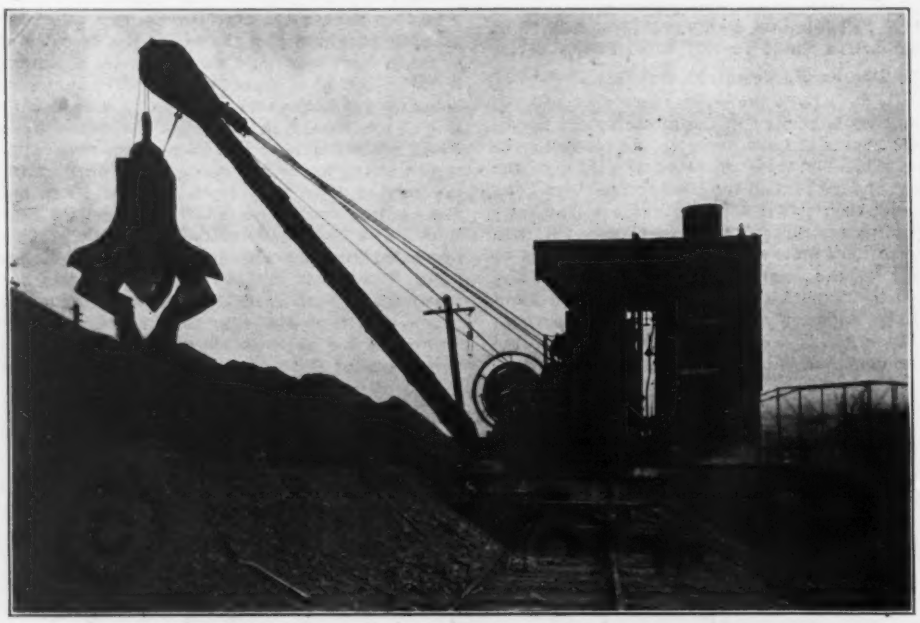


FIG. 6. LOCOMOTIVE CRANE WITH SPECIAL GRAB BUCKET FOR HANDLING ORE.
(This view shows machine unloading cars into stock pile.)

from the boat into cars, without the aid of hand shoveling or any other auxiliary appliances. These machines are built to handle grab buckets of from one to five tons capacity, a few even having ten-ton buckets. This is, however, too large a bucket to use satisfactorily in the smaller boats, as the hatches are too small to allow the buckets to pass through freely. These machines may have the trolley and bucket handled by a system of ropes and the operator stationed in the tower of the machine, or they may be arranged to have the operator ride on the trolley and have all the mechanism for operating bucket and trolley also placed on the trolley. Both arrangements are used successfully. The apron or cantilever extension over the boat is so arranged that it can be raised when not in use, and is out of the way in moving the boat. The whole machine can be traveled along the dock so as to reach the different hatches of the boat without moving the boat itself. Substantial dock construction is, of course, necessary to carry these heavy machines, which weigh from 150,000 to 300,000 lbs. or more.

The speed of the unloading machines varies greatly, of course, with the conditions under which the machines are working. The smaller machines will make from 40 to 100 trips an hour. If the machines with the five-ton buckets make 40 trips an hour, this would mean 2,000 tons in a day of ten hours. Some of the larger machines have handled ore at the rate of 500 to 600 tons an hour. The average would perhaps be from 250 to 300 tons an hour. The kind of ore being handled makes a great difference in the speeds and also in the quantity handled. The hard lumpy ores, of course, being much more difficult for the bucket to pick up than the soft fine ores. The arrangement and size of the hatches in the boat has also much to do with the speeds at which the machines can work.

During the past two or three years a good many men have been working to design a grab bucket which would successfully handle ore. A certain bucket may handle coal very satisfactorily, and yet a bucket built along the same lines may be a perfect failure when it is attempted to handle ore with it. Some of the first buckets built for handling ore were designed on the principle of the orange-peel bucket, which is used in dredging. The bucket was to pick up its load by digging. Later buckets have been designed to act first as a scraper, that is, the bucket first scrapes its load together and then picks it up. There are now on the market several buckets which handle ore very successfully. A view of one of these buckets in operation is given by Fig. 6.

One difficulty which all builders of ore-handling machinery have had to meet was the problem of how to remove the ore underneath the deck, between the hatches. It has usually been necessary either to shovel this ore by hand out under the hatch where the grab bucket could reach it, or shovel it into tubs and take it out in this manner. In the Hulett machines working at Buffalo, Conneaut and other places, this problem is solved by placing the bucket at the end of a vertical shaft, which can be rotated and also moved sideways. After the bucket has been lowered through the hatch, the arm or shaft is revolved and moved over to the side of the hatch, this carrying the bucket around underneath the deck, where it can reach the ore.

Scrapers of various kinds have been tried with more or less success for pulling the ore under the hatches, one of the most successful, perhaps, being an ordinary road scraper operated by winches on the deck of the boat.

In some machines which the Brown Hoisting Machinery Co. is now building for Conneaut Harbor the trolley is placed on a turntable. After the bucket has been lowered through the hatch the trolley is revolved and the bucket swung around underneath the decks. The spread of the bucket is made sufficient to reach from one hatch half way to the next, so that practically all the ore in the boat can be reached. These machines promise to supply a comparatively cheap device for removing practically all the ore from an ordinary boat without the aid of hand shovelers. This is, of course, what all builders of this class of machinery are striving for.

Ore unloading machines are such an important item in the transporting of ore and coal, that boats are now being designed with special reference to the economical working of the unloaders. The hatches are made practically continuous, and they are made as wide as the space used for the storing of the cargo. Fig. 7 shows the cross-section of one of these new boats. The shell is made double and all bracing required is placed in the space between the two shells. There is a width of 36 ft. which is left clear for the cargo. There are 33 hatches in a total length of 396 ft. In this length there is practically nothing to interfere with the working of the bucket. Boats of this type will no doubt soon be seen on the lakes.*

Where a part of the material has to be stored as it is unloaded, a different machine or machines must be used. Fig. 8 shows a type used in loading into cars and for storing a limited quantity of ore or coal. For small docks these are very satisfactory machines. Fig. 9 shows the method employed at Conneaut Harbor, where part of the boat's cargo may be loaded on cars for shipment and a large quantity put in stock temporarily. At the front of the dock there are direct unloaders similar to the machine described above. These machines load cars or dump into a pit at the rear of the machine. The portion dumped into the pit is picked up by the large bridge crane and carried back and dropped into the storage yard. When this material is required for shipment the large crane picks it up again and loads it into cars.

The direct unloaders have 5-ton buckets and the large crane a 7½-ton grab bucket. All of these cranes are designed to have the operator ride on the trolley. They are all operated by electric power. The trolley on the bridge has two 75-HP. motors for racking, and two 150-HP. motors for hoisting the load. The motors on the direct unloader trolleys are the same. It was desirable to have as few sizes of motors as possible. It is arranged so that the operator can move the crane itself by running the trolley to either the pier or shear, where the controllers for operating the bridge travel motor are placed.

Fig. 10 shows an arrangement used when the furnace is located on the shore of a lake or river, where boats can be unloaded directly at the furnace. The cranes take the material from the boat and put it in storage piles or in the bins shown near the furnaces. Material from the stock pile can be rehandled to the bins at any time as desired. Under the bins there are transfer cars or larries, as they are called, which take the material as it is drawn from the bins and carry it to the skip cars, by which it is taken to the top of the furnace.

When the furnace is at such a distance from the dock where the ore is unloaded from the boat that the ore must be hauled in cars, some arrangement must be used to unload the cars quickly upon their arrival at the furnace yard. If all the material was stored in the bins, the simplest method would be to run the cars up on top of the bins, and by using bottom dump cars the material could be dumped cheaply and quickly into storage, but usually provision must be made for the storing of many thousand tons beyond the bin capacity. Figs. 11 and 12 show modern furnace yards. Fig. 11 shows the yard of the Carnegie Steel Co., at Rankin, Pa. This view is interesting for showing the operation of a device for picking up and dumping bodily the ore cars into a

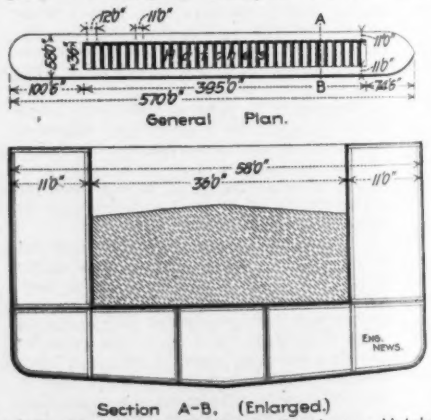


Fig. 7. Ore Vessel with Nearly Continuous Hatches to Facilitate Use of Mechanical Unloading Devices.

bin from which the material is drawn off into bucket cars. Fig. 12 shows the yard plant of the Crucible Steel Co., at Clairton, Pa. Some of the cranes used in furnace storage yards are huge af-

*Since this article was written, the "Augustus B. Wolvin" has been launched at Lorain. It is the largest vessel on fresh water. It is 560 ft. long, 56 ft. beam and has a molded depth of 32 ft. amidships. It has a continuous hopper 409 ft. in length without bulkheads of any kind. It has a width at the top of 43 ft. and at the bottom of 24 ft. There are 33 hatches 33 ft. x 9 ft. in the clear and 12 ft. c. to c. The boat is designed for a carrying capacity of 12,500 tons.

fairs, being designed to handle 10-ton buckets and to cover yards five or six hundred feet in width. Two of the largest cranes built are at the Carrie furnace plant, at Rankin, Pa.

Steel is rapidly replacing wood for the construction of storage bins for ore, limestone, coke and coal. The parabolic suspension type, as used by the Brown Hoisting Machinery Co., Fig. 13, is one of the latest, most economical and satisfactory forms in use. These bins are formed of steel plates about ⅜-in. thick, curved to the form

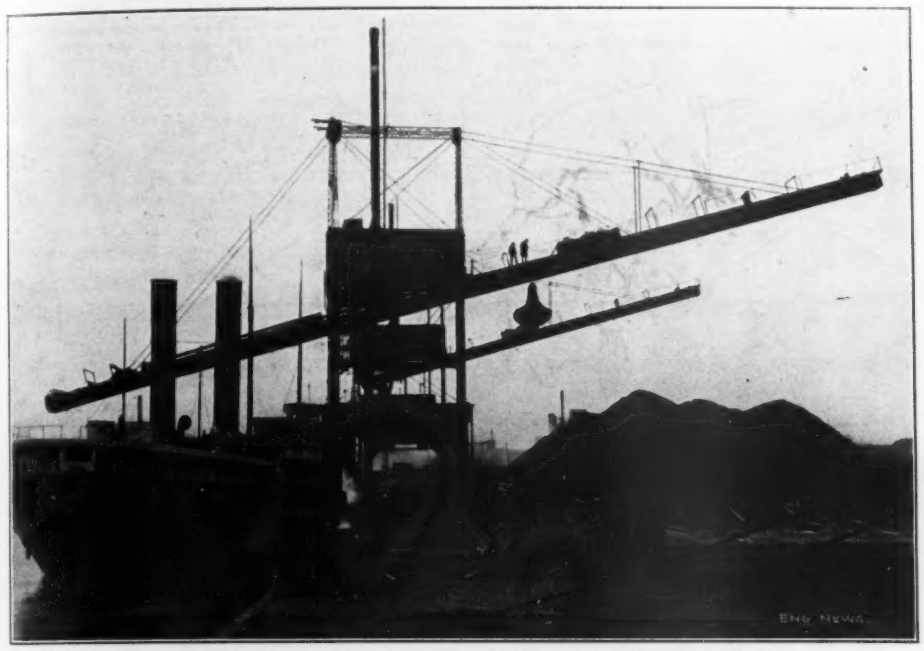


FIG. 8. TYPE OF UNLOADING MACHINE EMPLOYED WHERE ORE IS STORED, INSTEAD OF BEING TRANS-SHIPPED DIRECTLY ONTO CARS.

of a parabola and supported at their upper edges by longitudinal girders. Transverse girders placed 14 or 15 ft. apart hold the longitudinal girders in position, and also form the upper portion of partitions dividing the bins into pockets. The whole bin construction is carried on steel posts made wide and stiff in a direction at right angles to the axis of the bins. These columns are usually attached to the masonry foundation. The weight is ample, however, to resist any overturning action produced by wind forces. Where large bins for the storage of coke are required, these bins are built alongside and parallel to the ore bins; one side of the ore bins may even be used to form one side of the coke bins also. This makes a considerable saving in material.

The valves or spouts are placed at intervals of 3 or 4 ft. along the bottom of the bins, so that practically all the material can be drawn off through these valves. Steam cylinders or small motors are used to operate the valves, usually the latter. One operator can draw the ore, limestone and coke from the bins, weigh the ore and limestone, measure the coke, and also transfer and dump the materials into the skip car at the furnace.

At the smaller furnaces the bins for holding the coke are usually built in around the furnace incline and are arranged so that the coke can be drawn off from the bins directly into the skip, and larries are not used for handling this material, except at the larger furnaces or where it is desired to store in bins a large amount of coke requiring bins so large that spouts can not be arranged to reach the skip directly from the bins.

Coke bins are a comparatively simple affair, and yet a good deal of thought and time has been spent to produce simple and efficient spouts and mechanism for these bins. The coke is usually brought to the furnace in box cars or cars built especially for handling coke. These cars are taken up on top of the bins on trestles, and the coke dumped directly into the bins. Where larries are used to take the coke from the bins to the skip, these larries are usually similar to those for handling ore, but as the coke is not weighed, no scales are provided on these larries.

The hopper in the larries is usually designed to hold from one to two tons of coke, and it is arranged so that one operator draws the coke from the bins into the hopper on the larry, runs the larry to the furnace skip and dumps the load from the larry into the skip car. In the smaller furnaces, where the coke is drawn directly from the bins into the skip car, it is sometimes arranged so that the man who runs the engine also draws the coke into the skip car. This arrangement, of course, saves the labor of one man, who would be busy only a portion of the time.

Some of the larries used underneath the ore bins for transferring the material from the bins to the skip hoist are very interesting pieces of mechanism. They have buckets of from 75 to 120 cu. ft. capacity, with hinged doors at the bottom. They have scales for weighing the material and have an arrangement for throwing the load in the larries off from the scale beams, while the load is being carried along the runway. They have motors and mechanism to travel them along the tracks under the bins, and a small motor and mechanism for operating the bin-gates. This mechanism is connected with the mechanism which is attached permanently to the gate, by means of a short vertical shaft which has near its center a male and female coupling. This coupling is thrown into mesh by a foot lever on the larry and is provided with a hinged coupling, so that it can be thrown into mesh if the larry stops within 1 or 2 ins. of the central position. All the operations of drawing the material from the bins, weighing it, traveling the larry, opening the gate in the bottom of the hopper and dumping the load into the skip car at the furnace hoist are performed by one man. The larries complete with their mechanism weigh from 10,000 to 15,000 lbs. They are usually arranged to run on tracks made of ordinary railroad rails riveted to the top of I-beams or built girders. These tracks are supported about 4 ft. above the ground, which allows clearance for the hopper and also allows room for getting at the different parts for examination and repairs. Fig. 13 shows one of these larries.

The old method of charging the furnace by means of hand barrows is, of course, still employed at many of the small furnaces. These barrows may be filled by hand or the material may be drawn off into them from bins built near the hoist. At many furnaces these barrows are still taken to the top of the furnaces in vertical hoists or elevators. This arrangement requires men to be stationed at the top of the furnace, which is not necessary with the modern methods of charging. Two or three men operating modern larries and a furnace hoist of any of the later types will do the work which has previously been done by a large gang of men and at a very great reduction in cost.

One of the most interesting mechanisms at a furnace plant is a modern skip hoist. Fig. 14 shows a modern hoist and top. Some of these hoists are almost automatic in their operation. The material is taken up to the top of the furnace, dumped into the receiving hopper, and the car returns for another load with no more skilled attention being required than can be given by a fifteen-year-old boy. Simple yet ingenious appliances distribute the material evenly in the furnace, register the location of each load dumped on the bell, the height of stock in the furnace, the number of trips made by the skip to each furnace charge and the total number of trips made by the skip in any given time. As the skip car reaches the top of the furnace, its motion is checked and finally stopped automatically. Finally as the liquid iron is drawn from the furnace, it is cast into pigs, cooled and loaded on cars without the employment of hand labor, the movement of the iron from the time it leaves the furnace until it is loaded on cars being continuous.

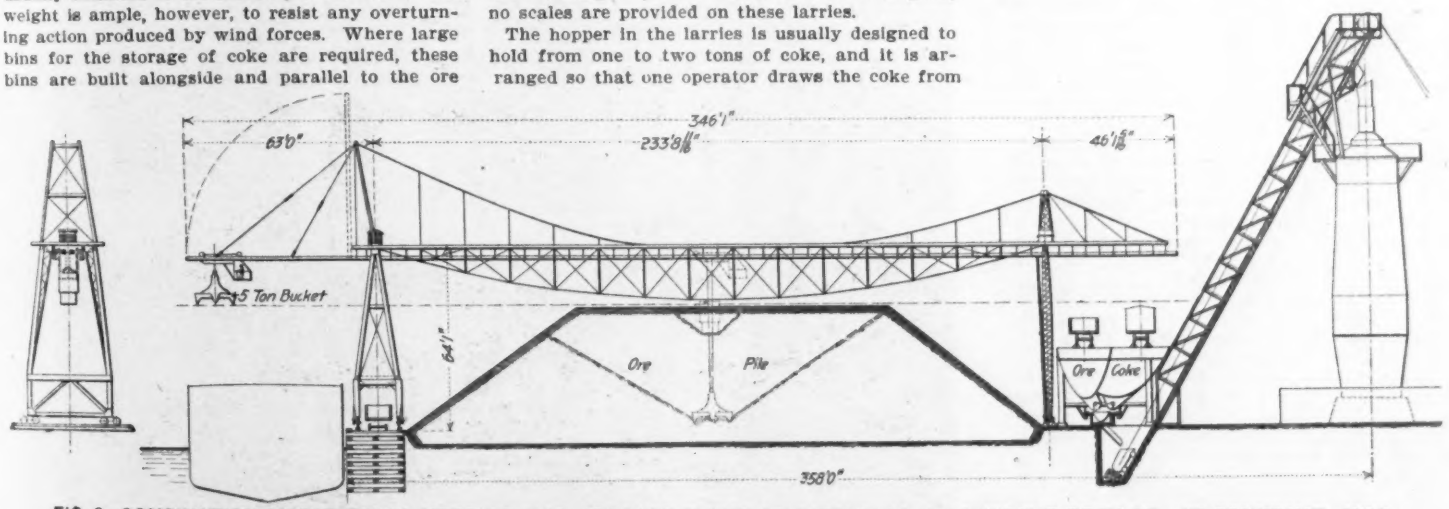


FIG. 9. COMBINATION DIRECT TRANS-SHIPPING AND STORAGE PLANT OF PITTSBURG & CONNEAUT DOCK CO., AT CONNEAUT, OHIO.

CAISSON ILLNESS AND DIVER'S PALSY; AN EXPERIMENTAL STUDY.*

By Leonard Hill, M. B., F. R. S.,† and J. J. R. Macleod, M. B.‡

A caisson consists of a steel cylinder which is sunk in water, and out of which the water is kept by means of compressed air. The men in the caisson are thus able to work on the bed of the river or the sea.

The top of the caisson is provided with an air-lock, a chamber fitted with air-tight doors and cocks, whereby the air can be compressed or decompressed as the men enter or leave. A large cock is utilized for rapid decompression during the passage of material, and a small cock for the slower decompression of men. The men frequently take advantage of the large cock, and by breaking the rules get out of the air-lock quickly.

Ten meters of water roughly correspond to 1 atm.; thus, for every 10 meters or 33 ft. a pressure of + 15 lbs. to the sq. in. or + 1 atm. is required to keep the water out of the caisson or diving bell. At a depth of 100 ft. a man would be exposed to + 3 atm., at 200 ft. to + 6 atm. In the case of a diver the conditions are the same. Compressed air is delivered through a tube to his helmet and escapes by a valve, by which means the water is kept out of his dress. The pressure of the air must always be just greater than that of the water.

The numerous accounts of caissoniers' and divers' sickness which have been published show that the sickness never attacks the men while under pressure, but only after decompression. The account of the symptoms given by Pol and Watelle‖ in 1854 may be taken as typical. These authors had charge of 64 men who were employed in a caisson on the banks of the Loire at + 3¼ atm. The men were compressed in 15 mins., worked for a 4-hr. shift, and were, according to the rules, decompressed in 30 mins.

The physiological effects observed in compressed air were very slight: pains in the tympanic membrane (relieved by opening the Eustachian tube); slowing of respiration and diminution in thoracic expansion; slowing of the pulse; increase of urinary secretion; a feeling of resistance to movement owing to density of the atmosphere; inability to whisper, attributed to the resistance of the compressed air to the finer muscular movements of the tongue. On decompression these authors felt a lively sensation of cold and a certain degree of breathlessnss; while the pulse accelerated. The cold is due to the expansion of the air.

Pathological effects: There were 47 men out of the 64 who stood the work more or less well; 25 were discharged owing to sickness; 2 died. The slighter attacks were 14, and the serious attacks 16 in number.

The accidents without exception occurred after decompression.

TYPES OF CASES.

(1) Embarrassed respiration, pains in the limbs, loss of appetite and digestive troubles, black stools, loss of flesh.

(2) A dazed condition, muscular pains and cramps, feelings of numbness, vomiting of black material. One day this man lost consciousness soon after decompression. The pulse was full and frequent, the face congested, the respiration short and stertorous with mucous rales. There was complete loss of muscular power. The man was bled, purged and blistered and recovered in four hours.

(3) Severe muscular pains with cramps, the skin cold, respiration embarrassed, the pulse small and slow.

(4) A comatose condition like to drunkenness, with indistinct speech, dilated pupils, accelerated respiration and rapid pulse. Diplopia, deafness and vertigo persisted.

(5) Severe pain in the limbs and chest, embarrassed respiration. The man was discharged. He returned to the work without permission. On decompression he suddenly fell unconscious and died in 15 mins.

(6) Great oppression, with dullness and bronchophony, a rapid pulse, cold skin, continual cough, and clonic contractions of the limbs. Better after 5 hours of care. On another occasion this man became comatose, with dilated pupils, loss of muscular power and subdelirium. He was bled; the venous blood was arterial in color. The man recovered and was discharged.

(7) Vision disturbed and double, hearing abolished, respiration frequent, pulse frequent and high tension. Bled, venous blood arterial in color.

(8) Pains in the head, vertigo, cramps.

(9) A powerful man, aged 40. Died immediately after decompression.

(10) Muscular pains. Cured by recompression.

(11) Very severe muscular pains, persisting for many days.

(12) A few minutes after decompression the man appeared to be dead; unconscious, livid face, dilated pupils, embarrassed respiration, indistinct trembling of the heart, no pulse, involuntary micturition, black vomit. Given hot baths and massage. Pulse returned in 30 mins. Very severe muscular pains, blindness and deafness, with a wretched pulse during the night.

Next day the man is better but mentally confused. He recovered, but feeble vision and dilated pupils persisted.

Pol once suffered himself from acute pain in the left shoulder or arm, with shivering and vomiting. It seemed to him that emphysema existed in these places. E. H. Snell likewise thought he could detect emphysema in one of the cases, of joint and muscular pain ("bends" or "la pressure") at the Blackwall Tunnel; while Bucquoy records that a cupping-glass, applied by a skilled assistant, would not hold on to a painful knee-joint owing to the gas set free in the subcutaneous tissues.

Among the numerous other reports collected together by Paul Bert* and recently added to by E. H. Snell,† we will quote some cases recorded by Babington and Cuthbert at Londonderry. The pressure reached 30 to 43 lbs.

As in all caisson works the men suffered joint muscular pains or from "bends."

CASES.

(1) The man suddenly fell unconscious on decompression after 4 hours at 28 lbs. He was cold and livid. There was right facial paralysis and strabismus; pupils immobile. Pulse, 150, small and irregular; heart sounds almost inaudible; respirations, 24 to 44, very irregular. Bled; blood very black. Died in 24 hours.

(2) Similar to (1) but no facial paralysis.

(3) Sharp shooting pains in legs and thighs; unable to walk, feet cold and numb; legs anaesthetic; was found with feet almost in the fire and toes badly burnt. Recovered in two days.

(4) Very similar to (3). Recovered in a few days.

(5) Fell helpless and semi-comatose during decompression. Could be roused to answer questions. Coma passed off in 18 hours. Totally paralyzed from fourth rib; retention of urine. Died 160 days after.

(6) Similar to (5), but paralyzed from eighth dorsal vertebra. Died after 30 days.

In sinking the foundation of a bridge at St. Louis, over the Mississippi, a high pressure of + 50 lbs. was used. The number of workers was 600, of whom 14 died and 119 were more or less affected.* On leaving the caisson the workers are stated to have been pale and fatigued. Involuntary contractions and nose bleeding occurred in some.

As the depth increased the illnesses became more numerous and severe. The men were not taken sick while in the caissons, but a few minutes to one hour after decompressions. At the greatest depth the shifts were reduced from 4 to 1 hour, and the engineer, Eads, states that this reduced the serious accidents to nil. Visitors who stayed but a few minutes, and the workers of the locks, who were quickly compressed and decompressed, never suffered. Fifty-three cases suffered from paralysis of the legs with, usually, epigastric pain. Nearly all these recovered in from one day to one week. The sudden deaths were preceded by coma, stertorous breathing and muscular spasms.

At Brooklyn Bridge 110 similar cases of illness occurred, with three deaths, as reported by Dr. Andrew Smith.† J. Hunter‡ stated that at the Forth Bridge works "the joint pain is of all symptoms the most constant, and almost invariably it attacks the knee alone, or with other joints, rendering its poor victims from its severity absolutely helpless. . . . Another prominent symptom met with was epigastric pain accompanied by vomiting."

The following interesting case is reported by Dr. Turgman in the files of the British Medical Journal for 1888. A man worked for 3 hours at + 60 lbs. He was decompressed in 3 mins. On the way home he was siezed with severe pain in the right elbow joint, a little later his right knee gave under him and he fell and became semi-conscious. Acute pain in both elbows and knees followed and 6 hours after decompression he was found cold and almost pulseless. He recovered, but spat blood for 3 or 4 days. Necrosis of the right femur followed and the leg had to be amputated. The cause of this was, no doubt, embolism of the medullary artery of the femur.

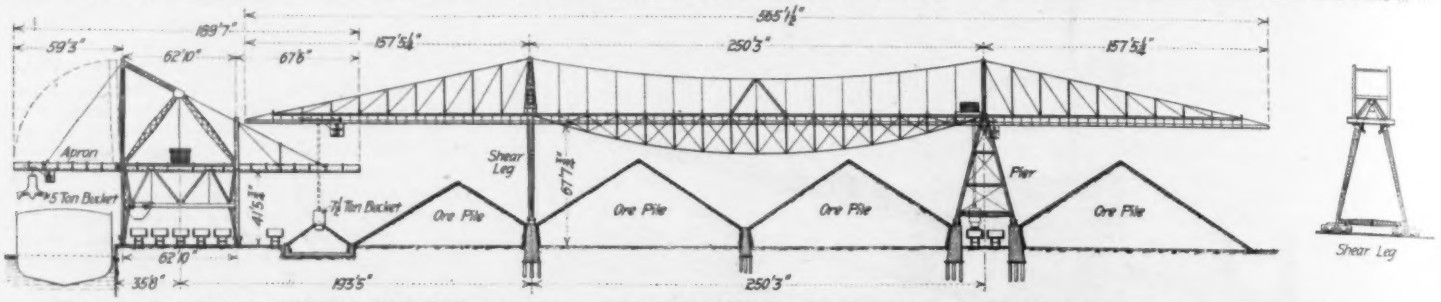


FIG. 10. PLANT FOR STORING AND FOR HANDLING ORE FROM VESSEL TO FURNACE, BUFFALO & SUSQUEHANNA IRON CO., BUFFALO, N. Y.

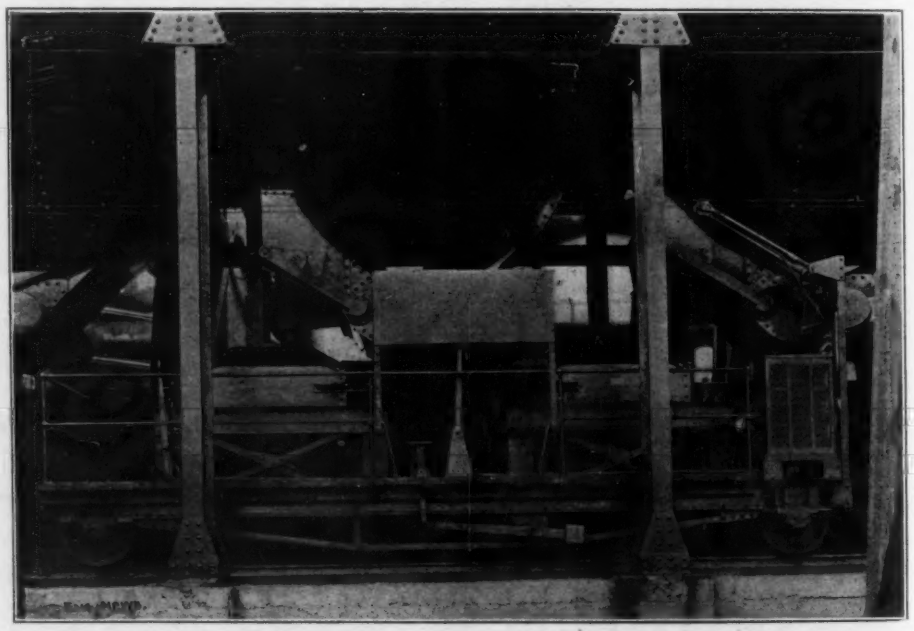


FIG. 13. PARABOLIC SUSPENSION ORE BIN, CLEVELAND FURNACE CO., CLEVELAND, OHIO.

*Abstract of an article in the "Journal of Hygiene."
†Lecturer on Physiology, London Hospital.
‡Professor of Physiology, Western Reserve University, Ohio.
‖Ann. d'hygiene publique et de med. legale, 1854. Cit. after Bert, La Pression Barometrique, p. 390.

*La Pression Barometrique. Paris, 1878.
†Compressed Air Illness. London, 1896.

*Cit. after E. H. Snell. Compressed Air Illness. 1896.
†Effects of Compressed Air. Detroit, 1886.
‡Edinburgh thesis, cit. after Snell.

The following account given by one of the caissoniers in the Blackwall Tunnel gives a graphic picture of the less grave form of accidents:

What did it feel like to go in? Oh, just the same as anywhere else. You felt a wee bit giddy when you went in, that was all.

We stayed in for eight hours at a shift. We had half an hour for dinner, but some of the men would not come out for it. They took it inside with them. Coming out again it was not so bad, but just chilly; bitter chilly, cold as charity. The pains would come on afterwards, in an hour or so, or when you got into bed. Bends in the back, and the wrists, and the legs; just awful. Men would turn out in the middle of the night and come back to the works and get into the compressed air again in the medical locks. They had a full dose of it for a start, and let the pressure drop gradually. Then they went back home to bed. Do them any good? Eh, mon, it's no for me to say. They said so, but I thought it was only humbug, a faith dodge. When I had bends I just jumped about and took a drap of guid whuskey—better than all your doctor's concoctions.

The symptoms of the men employed at Blackwall have been fully reported by E. H. Snell (loc. cit.). Snell especially brought into notice cases of auditory vertigo.

In none of these cases the vertigo occurred without deafness. The vertigo was increased by moving the head in one particular direction and was frequently accompanied by vomiting and mystagmus.

That very prolonged exposure to compressed air is harmless is shown by the fact that mules were kept in the Hudson caissons (at + 2.3 atm.) for many months, and were sold for a good figure at the end (E. W. Moir*).

Von Schrotter† has studied many caisson cases at Vienna where the depth of the water was 25 meters. In one case a strong, healthy man, aged 36, worked at +2½ atm. for the first time from 10 p. m. to 2 a. m. without any trouble. Half an hour after his ascent he was seized with intense pains in the limbs, with great difficulty in breathing. He soon could not stand and lost consciousness.

FIG. 14. FURNACE HOIST AND TOP, LA BELLE FURNACE, STEUBENVILLE, OHIO.

I never felt happier than when I was in the compressed air. Always happy, and on the cherry side. Why, laddie, I would get up in the morning feeling very dour and queer, and just go into the workings, and then whistle and sing all day long. Not that you could hear the whistling, at least a man with my lungs, when the pressure was over twenty-five.

The worst thing that could happen was for the electric light to fail. Then they burnt candles, and the mixture of smoke with the air gave them "bends" of an extra special vigor. (He was in the No. 3 caisson, where the pressure was as high as 37 lbs. to the sq. in. The effect of that abnormally condensed atmosphere was to cause an overpowering sleepiness.) You nodded and didn't care if you went to sleep for ever, though it was all very nice and dreamy. When I was alone in that "casoon" I had to rope myself up lest I should fall asleep and tumble to the bottom, 60 ft. below. It was better under the river than in the "casoons," because under the river the air could escape into the Thames. Tobacco had no sting. Even Irish roll had lost its savor. The only stuff that had any flavor was four-ale. You weren't allowed to take it in, but you did. But you had to take the cork out first. If you didn't, the bottle would burst. The finest men in the tunnel were the first to be knocked out. The men of delicate appearance stood the pressure best.

There was now great dyspnoea, an intermittent pulse, cyanosis of the face, and fine rales over the lower lobes of the lungs. The face became livid, the pulse almost imperceptible. After ether injections and artificial respiration consciousness returned. The patient complained of great pain, and especially in the right arm, and of feeling cold. He could not move. Temperature 36° C. Profuse sweating. The respiration was cartal and the diaphragm fixed in the expiratory position. The man gradually recovered, but two months later there was still some loss of motor power, patches of hyperalgesia, increased knee jerks, pains in right elbow and left knee, loss of sexual power, and inability to hold urine more than one hour. There was evidently a lesion above the origin of the phrenics in this case, producing the immobility of the diaphragm and arm symptoms. Probably there was another lesion in the lower dorsal region.

*The Blackwall and other Subaqueous Tunnels. Journ. Soc. Arts, May 15, 1896.

†Prager med. Wochenscrift, XXIV. 1899, Nr. 14.

CASES OF DIVER'S SICKNESS.—In the case of diver's sickness a large number of reports have been gathered together by Bert. M. Denyreuze,* reported on 200 men who dived to a pressure of + 3 to + 4 atm. During six months' work five men died and a great number were affected, most commonly with paralysis of the legs and bladder and deafness. The men who quickly returned to the surface suffered most. None of the deaths occurred while the men were under water. M. Gal recorded the following typical cases occurring among the Greek divers:

(1) Submerged for 15 mins. at 40 to 45 meters (+ 4 to 4½ atm.). Some minutes after returning to the boat the diver complained of dizziness and fell down and died.

(2) Submerged for 45 mins. at 40 meters; 15 mins. after being pulled up he was seized with pains, and almost at once lost consciousness and died.

(3) Thirty mins. after return to the boat was seized with severe pain in the epigastrium. Became paralyzed in legs, bladder and rectum. Died after three months.

(4) Became paraplegic shortly after return to boat. Cured in three months.

(5) Depth 35 to 45 meters; paralysis of legs; cured in five days.

Messrs. Siebe and Gorman tell us that among the Greek divers about a score of lives are lost every year.

Through the agency of Messrs. Siebe and Gorman we circulated among the pearl divers of Australia questions concerning the illnesses of divers. The divers there go to 100 ft. and very rarely to 125 ft. In shallow water they work for two hours, in deep water for 15 to 20 mins.

The symptoms of illness occur directly or soon after the diver comes on deck. There is no pain whilst on the bottom but directly the diver comes to the top. The pains occur in the hips and knees, the calves of legs and arms. Paralysis of the leg and incontinuence of urine are the graver symptoms.

The following are extracts from the records of the autopsies which have been made after deaths due to caisson illness and divers' paralysis.

AUTOPSIES OF CAISSONIERS.

(1) General congestion of the viscera, patches of congestion on the brain.

(2) General subcutaneous emphysema. Congestion of viscera and especially of lungs. A heavy man, aged 40. (Pol and Watelle.)

(3) Interlobar emphysema of lungs, numerous punctured ecchymoses on the pleura and pericardium, bubbles of gas within the blood vessels. Death from bursting of caisson. (Gallard.)

(4) Softening of some inches of the spinal cord in the dorsal region. (Bert.)

(5) Extravasation of blood upon the spinal cord opposite the two lower dorsal vertebrae. (A. Smith.)

(6) Extravasation of blood upon, and softening of spinal cord, hemorrhages in the kidneys. (Jaminet.)

(7) Death 15 days after decompression. Numerous foci of hemorrhages and signs of acute myelitis. Small, irregular fissures in mid-dorsal cord filled with round cells. From their well-defined edge probably produced by escape of gas. (v. Leyden.)

(8) Death 2½ months after decompression. Disseminated myelitis in dorsal region with fissures suggesting laceration of the tissues. (Schultze.)

(9) Death on third day. Fissuring and laceration of spinal cord. (Ziegler's Beitrage, 1892.)

AUTOPSIES OF DIVERS.

(10) Hemorrhages in or upon spinal cord. (Gal, Greek divers.)

(11) Hemorrhages in or upon spinal cord. (Blick, Australian pearlers.)

THEORIES OF COMPRESSED AIR ILLNESS.

The phenomena observed in local compression of the body and in cupping, the pallor of caissoniers, the nose-bleeding sometimes seen on decompression, the congestion of the viscera recorded in a few autopsies, have led most medical men who have observed caisson sickness to suppose that the blood is driven from the exterior and compressed within the viscera.

"Pulmonary and cerebral congestions are," say Pol and Watelle, "the chief results of compressed air. Just as a lowered atmospheric pressure brings blood to the exterior and causes hemorrhages, so does compressed air congest the viscera." The brain and spinal cord, according to Babington, shut up in their osseous cavities, are not able like other elastic parts, to quickly accommodate themselves to changes of pressure.

Bouchard put forward the extraordinary theory that as the gases of the intestine are compressed and abdominal wall becomes concave, and as the abdominal wall resists this distortion it converts the abdomen into a kind of cupping-glass. This leads to congestion of the abdomen during compression, and the reverse on decompression.

A. H. Smith may be quoted as the chief exponent of the mechanical congestion doctrine. He deduced "the law that under high atmospheric pressure the centers will be congested at the expense of the periphery . . . and that firm and compact structures will be congested at the expense of those more compressible. Moxon,† in his Croonian Lectures, said "it needs no experiment to show

*Loc. cit. p. 413.

†Lancet, 1881.

that great increase of atmospheric pressure must drive the blood away from the surface of the body."

The neglect by these writers of physical laws is the less excusable, seeing that Poisseuille,* in 1835 observed the capillary circulation in frogs, and young mice, enclosed in a glass chamber and submitted rapidly to + 2 to +8 atm. The circulation continued unaffected. Moreover, Paul Bert, in 1881, clearly stated the physical error contained in such theories. The body of a workman exposed to compressed air supports, according to Guerard:

at + 1 atm. an additional 15,500— 20,000 kilograms
at + 3 atm. an additional 46,500— 60,800 kilograms
at + 6 atm. an additional 93,000—123,600 kilograms

If it were not for the incompressibility of the fluids of the body, and the equal and instant distribution of the pressure to all parts, life would be impossible under any variation of atmospheric pressure. The fact that mere mechanical pressure is of no importance is shown, not only by Guerard's figures, but by the existence of abundant life in the sea at depths of 2,000 meters, corresponding to a pressure of + 200 atm. The only mechanical compressions which can take place are that of the membrana tympani, which is relieved by opening the Eustachian tube, and that of the intestinal gas. The latter leads to the workmen tightening their belts and to a freer descent of the diaphragm in respiration. It has astonished us to find the most experienced practical men in diving and submarine engineering unaware of the experimental work of Paul Bert, of the conclusion which he drew as to the causation of compressed air illness, and of the precautions which he laid down for the guidance of caisson workers.

Paul Bert by his remarkable experiments, published in 1878, proved that the true cause of caisson sickness is the effervescence of gas in the blood and tissue juices. This explanation had, it is true, been advanced by several authors, such as Hoppe (1857), Francois, Rameau, Bucquoy, etc., but generally as a cause additional and subsidiary to mechanical congestion.

Bert found by analysis of the gases of the blood that the nitrogen increases in compressed air more or less according to Dalton's law. He found that this gas was set free on rapid decompression, and produced embolism, in the lungs, the central nervous system, etc., and that the gravity of the result depended on the height of the pressure, the length of exposure, and the rapidity of decompression. He also proved that the gas set free in the tissues might produce local swellings and emphysema.

The truth of Bert's explanation is borne out by the varied nature of the lesions found in caisson sickness, by the subcutaneous emphysema which has been detected in a few cases, and by the autopsies which have been recorded. One man is struck with pain in the joints and muscles, and another with respiratory embarrassment and loss of consciousness, another with deafness and vertigo, and yet another with paraplegia.

All becomes clear if the cause is once accepted to be local embolism or compression by air bubbles. Thus air bubbles in the posterior roots or posterior columns of the spinal cord may cause the intense pains so often experienced. Air frothing in the heart may kill one man, air in the heart or in the vessels of the lung, or in the respiratory nervous system produce in another difficult breathing, air embolism in the brain may cause loss of consciousness or sudden death, or in the dorsal cord render paraplegic others, while a bubble in a semicircular canal will explain the cases of auditory vertigo, and bubbles in the joints and muscles cause local swellings and emphysema coupled with pain. Bert also found that high oxygen tension acts as a general protoplasmic poison arresting metabolism, depressing the body temperature, and causing the discharge of convulsions in mammals, and finally the death of all forms of life.

Since the publication of Bert's results little experimental work has been done on the subject. The most important paper is one by Lorrain Smith,† who has found that high oxygen tension produces inflammation of the lungs. During the last few years we have been reinvestigating the effects of compressed air and oxygen, and we propose to communicate the results obtained so far, under the following headings:

(1) Effects on the respiratory exchange and body temperature.
(2) Effects on the nitrogen output.
(3) Effects on the lungs.
(4) Effects on the neuro-muscular system.
(5) Effects on the central nervous system.
(6) Effects on the blood gases.
(7) Effects on the circulation.
(8) The effects of decompression.
(9) The rules of safe working for caissoniers and divers.

EFFECTS ON THE RESPIRATORY EXCHANGE AND BODY TEMPERATURE.

Bert enclosed animals in a small air-tight chamber and exposed them to increased pressures of air or oxygen. The chamber was not ventilated, and the animals were left till they died, when the air in the chamber was analyzed.

We have studied the respiratory exchange in animals placed in a pressure-chamber and ventilated with a current of air or oxygen. The chamber was fitted with thick glass windows and a pressure-gage. It was connected by an inlet tube with a bottle of compressed air or oxygen (Brin's), while an outlet tube, controlled by a screw tap, was connected with a set of Haldane-Pembrey absorption tubes and a gas meter. The outputs of CO_2 and H_2O were obtained by weighing the absorption tubes. The animals were given a wool bed to prevent their losing heat directly to the metal walls of the chamber, and the chamber in some cases was heated on a sand-bath, and the temperature of the outgoing air taken.

In the Journal of Physiology (XXIX., p. 492, 1903) we have published examples of the results we have obtained from mice. We concluded that compressed air at a pressure of + 4 atm. and upwards diminishes the CO_2 output and lowers the body temperature of mice. This effect generally increases as the pressure rises, but the individual power of resistance differs greatly in different animals. Paul Bert says that* the absorption of oxygen and elimination of carbonic acid diminish in proportion as the tension of oxygen rises, and that an animal breathing pure oxygen at 2, 3, 4, atm. is in the same condition as another breathing air at pressures of 10, 15 and 20 atm.

We have also observed, with the microscope, the capillary circulation in the frog's web and bat's wing, the animals being placed in a chamber fitted at either end with glass windows. The web or wing was spread over one window and illuminated with the arc light. We could detect no change either in the caliber of the blood vessels, or the rate of flow, when the pressure was quickly raised to + 20 to 30 atm. Neither did any change occur on rapid decompression, that is, until gas bubbles frothed off from the blood.

These experiments prove, then, once and for all that the pressure has no mechanical effect on the circulation, and they overthrow all the mechanical congestion theories of caisson-illness.

EFFECTS OF DECOMPRESSION.

Out of 24 dogs exposed by Bert to 7 to 9½ atm. and then rapidly decompressed in one to four mins., 21 died from the setting free of gas in the blood and tissues and only one escaped without symptoms.

Out of three cats exposed to 0.8 atm. and decompressed in two to three mins., one died in 15 mins., and the other two became paralyzed with softening of the spinal cord.

Three rats exposed to 5½ to 6½ atm. survived rapid decompression, while two at 8 atm. died.

Seven rabbits at 6½ atm. survived rapid decompression.

The most striking of Bert's results is the following: A dog was put at 9½ atm. The apparatus burst. The dog instantly died. Enormous subcutaneous emphysema was found, with gas in stomach, omentum, anterior chamber of eye, cerebro-spinal fluid and spinal cord. The right heart was full of gas, which, on analysis, yielded 15.2% CO_2, 82.8% N_2, and 2.0% O_2.

Having observed the effect of rapid decompression, Bert found that dogs may be safely exposed to + 10 atm. if 1 to 1½ hours be taken for decompression. The animals must, of course, not be exposed too long, or oxygen poisoning will result.

G. Thompson† compressed monkeys, cats, dogs, and pigeons to + 4 to 4½ atm. of oxygen or air for 1½ hours; there were no symptoms unless the decompression were too rapid. A dog stood a pressure of + 8 atm. for some time without discomfort. He then had a slight convulsion, but was all right after decompression.

Hersent exposed seven dogs to + 5 atm. for a few hours and decompressed them in 1 hour to 1 hour 15 mins.

No symptoms resulted 18 times. Slight paralysis of the legs occurred four times. Paraplegia, cured in five days, occurred once. Death with gas in the heart resulted once. One dog decompressed in 50 secs. died. Two dogs decompressed in 15 mins. had paraplegia, and one died.

Hersent also exposed dogs to + 3 to 3.8 atm. for times varying from 11 mins. to 4 hours 11 mins. The decompression lasted only 30 secs. to 50 secs.

Out of nine exposures, there occurred two cases of severe paralysis and death with bubbles in the spinal vessels, and two cases of temporary paralysis of the legs. All these experiments show the frightful risks of rapid decompression and that even one hour for decompression is not quite sufficient for a four hours' shift at + 5 atm.

Hersent‡ exposed a man to + 5.4 atm. for one hour and decompressed him in three hours. Itching and "bends" were not prevented, but no serious illness resulted.

The following preliminary experiments were carried out by one of us (L. H.):

(1) Two large toads compressed for one hour in 20 atm. O_2 and rapidly decompressed. The animals went into tetanic spasms, and swelled to double their size with the gas set free in their tissues. The heart was enormously distended, tense and scarlet in color. On letting out the froth it began to beat vigorously.

(2) Toad in 20 atm. O_2 for 5 mins. Decompressed in 1 min. There was some temporary paralysis of the legs and inertness. The animal soon recovered and hopped away into a corner. The same toad was placed in 20 atm. O_2 for 35 mins. After rapid decompression it was found alive, breathing and trying to escape. In about 1 min. there followed tetanic spasms and rigidity of the legs. The heart was enormously distended, immobile, scarlet and tense. On letting out the froth it began to beat. Gas bubbles were seen in the walls of the intestine, in the lymph spaces, in the anterior chamber of the eye, in the pial vessels, etc. The lungs were enormously distended. The nerves and muscles were excitable, and the muscles contracted vigorously.

(3) Rat raised to 15 atm. O_2 in 4 mins., then rapidly decompressed. The rat violently cleaned its face, there was tremor and tendency to spasm. The animal remained dull and inert, but recovered next day.

(4) Rat in 20 atm. O_2 for 6 mins. Rapid decompression. Respiration almost failed, tendency to tetanic spasms, paralysis of hind legs, contracted pupils, died in 80 mins. Air bubbles were found in the liver, mesenteric vessels, numberless small ones in the mesenteric fat in the uterus and foetal membranes (the rat was pregnant). The spleen and intestines were greatly congested. There was almost no blood in the heart. No naked eye hemorrhages in the C. N. S.

(5) Rat to 20 atm. O_2 in 5 mins. Decompression to 7 atm. in 10 mins. and to 0 rapidly. Immediate convulsions, eyeball projecting, tetinal hemorrhages seen with ophthalmoscope, died in 10 mins. Froth in the heart, and bubbles in the intestinal vessels and walls. No naked eye hemorrhages in C. N. S.

(6) Rat in 20 atm. O_2 for 2 mins. Decompression in 1 min. Rapidly cleaned face, dazed condition, a touch caused a violent jump like in first stage of strychnine poisoning. Recovered.

(7) Rat in 20 atm. O_2 for 5 mins. Rapid decompression. Lay on its side partly paralyzed. Soon recovered and moved into cage. On pulling it out it struggled, and this caused a violent epileptic fit (due to displacement of gas bubbles by the struggling?). It quickly recovered and ran into the cage.

(8) Rat in 20 atm. O_2 for 9 mins. Rapid decompression. Collapse paralysis, gasping respiration and death. Air bubbles everywhere in the right heart, liver, stomach and mesenteric vessels. General emphysema of the fat and connective tissues.

(9) Guinea pig in 10 atm. O_2 for 2 mins. Rapid decompression. The animal at first appeared dazed but soon recovered.

(10) Guinea pig to 22 atm. O_2 in 4 mins. Rapid decompression. Convulsions, rolling over to right, death. Froth in the heart and lungs. Some air bubbles in wall of intestine. Small pin point hemorrhages over base of brain. A few bubbles in the larger pial vessels.

The microscopical examination of the organs of these animals was carried out by Dr. Finlayson. In the central nervous system the gas bubbles formed small cystlike cavities surrounded by compressed and flattened nerve cells. The same kind of cavities formed in the liver. The bubbles set free in the vessels run together at less resistant points and the vessels become alternately occupied with columns of corpuscles and long bubbles of gas. Bubbles are also set free in all the connective tissue (lymph) spaces throughout the body and especially in adipose tissue. We have never seen bubbles actually within a muscle-fiber, nerve or other cell. The cells are not torn, but compressed and rendered anaemic. It is easy to conceive how the escape of gas bubbles into resistant structures, such as bone, aponeurosis nerve-roots and nerve-sheaths may give rise to the "bends" or pains so commonly suffered by caissoniers. V. Shroetter has published a figure exhibiting the air-bubbles in the coronary artery of a dog decompressed rapidly from 4 atm. He also gives a figure of the lesions produced in the spinal cord by the air-bubbles.*

We have actually observed the production of air embolism in the vessels of the frog's web and bat's wing. The animals were exposed to 20 atm. for about 10 mins. For about a minute after rapid decompression the circulation continued unaltered, then small dark bubbles were seen, first one, and then another, and then numbers scurrying through the vessels, and driving the corpuscles before them. In a moment or two the vessels became entirely occupied with columns of air bubbles, and the circulation was at an end. By means of rapid recompression we have driven the gas again into solution, and have seen the corpuscles reappear in the capillaries and the circulation become re-established. On very slowly decompressing the animals we have seen no gas bubbles appear.

Our large pressure chamber, pump and other facilities kindly provided by Messrs. Siebe and Gorman, the well-known marine engineers, has enabled us to thoroughly study the effects of rapid and slow decompression. The chamber was provided with a large tap, by means of which the pressure could be lowered from +7 atm. to +0 in about 10 secs. to 1 min.

It was also provided with a pin point opening through which the period of decompression could be made to occupy 1, 2 or more hours.

Experiment 1. A large cat, two half-grown rabbits, two large rats, and two white mice were placed in the chamber and the pressure raised to 105 lbs. (+7 atm.). A ventilation current was maintained. All the animals appeared to be perfectly normal. At the end of an hour rapid decompression was brought about. The chamber

*C. R. Acad. des Sci. II., 554.
†Journal of Physiology, XXIV., p. 14. 1899.

*La Pression, Barometrique, p. 612.
†New York Med. Record, 1889.
‡Cit. after Snell, p. 149.

*Prager Med. Wochenschrift, XXIV., 1899, No. 14.

filled with mist owing to the cooling of the expanded air. When the mist cleared we saw that the cat and one rabbit were dead, while the other rabbit was in violent tetanic convulsions.

On opening the chamber the rats were found to be dead.

The second rabbit died also and the mice alone survived.

There was emphysema of all the tissues and frothing of the blood in the right heart and lung. In the albino rats we could see extensive retinal hemorrhages.

(2.) A cat was placed in the chamber and the pressure raised to +7 atm. in 50 mins., and then rapidly lowered to +0. The cat survived, for the tissue fluids had not become sufficiently saturated with air.

Our blood-gas analysis show that it requires an exposure of about 1 to 1½ hours at +7 atm. to saturate the arterial blood with N_2 to the amount required by Dalton's law, and the tissue fluids must take far longer.

(3.) A large cat, a rabbit, two white rats and two mice were compressed to +7 atm. in 50 mins., and kept at this pressure for 1 hour. Decompression occupied 1 hour. None of the animals showed any discomfort.

(4.) A Rhesus monkey, a rat and two mice were compressed to +7 atm. for 4 hours. The animals seemed untroubled by the pressure. Decompression was started at 4.30 p. m. by opening the small tap; the last part of the decompression was hastened and when at 5.25 the pressure registered 10 lbs. to the sq. in., the large valve was opened and the pressure quickly brought to zero. On opening the chamber the monkey and the other animals seemed perfectly normal. On removing the monkey from the chamber he struggled to escape, but in the course of a minute or two suddenly became quiet and lay on his side gasping, with a peculiar cry. He gradually got more and more dyspnoeic, and his lips, tongue and face became markedly cyanotic. Despite energetic artificial respiration he died in about 10 mins. after removal from the chamber.

Post mortem. Heart: Not markedly distended, ventricles, in "delirium cordis," auricles beating feebly. On opening the right heart a little deep purple frothy blood exuded, followed soon however by non-frothy blood. Mesenteric veins. Small air columns in several of these. Lungs perfectly healthy.

The other animals in this experiment did not show any decompression symptoms. The cause of the trouble was no doubt the acceleration of the last part of the decompression.

(5.) The experiment was repeated with another monkey (Rhesus). After being subjected to +7 atm. air for 4 hours, 2½ hours were taken to decompress. There was not the slightest signs of decompression symptoms.

This experiment was repeated on this monkey three or four times a week for a month, the time for decompression being in each case 2 hours. There was never the slightest sign of decompression symptoms and the monkey remained in perfect health and maintained its weight. Towards the end of the period of compression it sometimes seemed to become sleepy. The body temperature remained normal.

THE TREATMENT OF THE DECOMPRESSION SYMPTOMS.

As we have shown in the experiments on the frog and bat the bubbles of air which develop in the capillaries can be seen to pass back into solution by a rapid re-application of the pressure.

We have tried this in the case of larger animals.

Experiment 6. A large hutch rabbit was kept under a pressure of +7 atmospheres of air for 4 hours and was then quickly decompressed. In a minute or so the rabbit developed typical decompression symptoms (i. e. fell on side and limbs showed tetanic convulsions). The pressure was now quickly re-applied up to about +5 atm. by emptying a large cylinder of compressed air into the chamber. The symptoms however, remained unabated and the rabbit soon died. It was evident, therefore, that for the re-application of pressure to be of any avail, the pressure must be very quickly re-established and no time be given for the air bubbles to tear up and damage permanently the nervous tissues, nor to produce stasis of the circulation for too long a period.

We, therefore, repeated the experiment with the modification that the pressure was more quickly re-applied.

(7) A cat and a hutch rabbit were subjected to an air pressure of +7 atm. for 4 hours. Decompression was affected to zero in about five seconds, and as quickly as the taps could be opened (about five seconds) a large cylinder of compressed air was delivered into the chamber, thus raising the pressure to 95 lbs. in about 2 mins.

At the moment of decompression the cat sprang to the window, excited and with widely dilated pupils. In a few seconds it became entirely paralyzed in the limbs so that it fell helpless on to its side, its head meanwhile showed continuous side to side pendulum movements. There was no mystagmus. On recompression, these symptoms gradually disappeared, the head movement being the first to go, then the pupils contracted to their normal size. Some 2 or 3 mins. after recompression to 95 lbs. the cat tried to move about but on each attempt fell helpless on its side. It soon gave up these attempts and lay in a semi-dazed condition. The pressure was maintained for 45 mins. and then slowly lowered. The cat recovered and on removal seemed perfectly normal, and on being placed in his basket leapt over its side and escaped into the room. Next morning it was quite normal in every respect.

The rabbit was recomposed before it showed any symptoms of decompression and was quite normal on removal from the chamber.

All our other experiments on metabolism, oxygen poisoning, etc., show that for +7 atm. (105 lbs.) 40 mins. is a safe period for decompression. The only cases in which it fails is when the animals have developed symptoms of oxygen poisoning and have become comatose, their body temperature lowered, and lungs congested by too long a stay in the compressed air. The circulatory and respiratory organs then fail to rid the body of the gas with which it is saturated.

Our experiments confirm those of Bert.

The blood and tissue juices effervesce on rapid decompression like an opened bottle of soda water. The longer the shift the greater becomes the saturation of the body fluids, and the greater the risk of rapid decompression.

A 5 mins. exposure to +20 atm. O_2 is sufficient to saturate rats and guinea-pigs so far that they die on rapid decompression.

Animals can be exposed to +7 atm. air with perfect safety for 4 hours and be brought out quite well when the period of decompression is made to last 2 hours.

Recompression, after rapid decompression, causes solution of the gas, and may, if quickly applied, save the life of the animal. Recompression has been found to alleviate the bends in most caisson works, and Mr. Moir introduced a boiler at the Hudson tunnel wherein recompression was applied with excellent results. At the Blackwall tunnel a "medical lock" was likewise employed and the cases of bends frequently derived benefit from recompression followed by slow decompression. V. Schroetter, from his experience at Vienna caissons, considers recompression to be the sovereign remedy for caisson sickness if it can only be applied in time.

We will now contrast the experimental results with the periods of decompression employed at some of the chief caisson works, and then discuss the influence of age and habit of body on caisson illness.

Periods of Shift and Decompression at Caisson Works.

Atmosphere (max.)	Length of shift.	Period of decompression.	Place.
4½	4 hrs.	30 mins.	Chalonnes.
2	.....	10 "	Lorient.
3½	4 hrs.	12 to 15 mins. (rule often broken by men)	Kehl.
3½	.....	20 mins.	Trazegmies.
3	8 "	4 to 5 "	St. Louis.
3½	4 "	10 "	"
4	3 "	18 "	"
2 to 3	8 "	4 "	Blackwall.
	(often shortened to 30 secs. by men breaking the rules.)		

Triger recommended 7 mins.

Barella recommended 10 mins. per atm.

Foley recommended 3 mins., and considered slow decompression dangerous.

The Greek divers are usually pulled up rapidly.

Denayranze for divers recommended 1 min. per meter.

Siebe and Gorman recommended deep divers to take 20 mins. in ascending.

Paul Bert recommended short shifts and 30 mins. decompression for 2 to 3 atm. and 60 mins. decompression for 3 to 4 atm. The decompression chamber must, he says, be warmed.

For deep divers he recommends a half-way resting stage.

INFLUENCE OF AGE.—Pol and Watelle state that young men of 18 to 26 years stand the work best; out of 25 men discharged on account of symptoms 19 were over 40 years old.

E. H. Snell found that at the Blackwall tunnel men below 20 were immune to accidents of decompression. This agrees with the general tenor of experiments on animals. The young bear rapid decompression best. He publishes the following table:

Age.	No. of men passed.	No. of cases taken ill whose ages are recorded.	Illness.
15 to 20.....	55	0	0.0%
20 " 25.....	145	15	10.3%
25 " 30.....	152	37	24.3%
30 " 35.....	91	19	20.9%
35 " 40.....	61	14	22.9%
41 " 45.....	38	10	26.3%
45 " 50.....	3	5	166.0%

HABIT OF BODY.—In stout men or men of heavy build the liability to illness is greatly increased. A. Smith compiled the following table from the records, at Brooklyn Bridge, of men under 45 years:

	Spare.	Medium.	Heavy.
Lost little or no time from sickness	25	14	3
Taken sick	28	22	36
Paralyzed	2	3	8
Died	..	..	3

Considering that under 45 years heavy men are greatly in the minority, this report is most striking. Snell excluded old and heavy men from the Blackwall tunnel caissons, and lost no cases. Men prematurely grey and with commencing arterial degeneration should also be excluded.

There is no clear proof that long continuance at the work renders a man immune. Cases frequently occur among old hands. The men among the new hands who are liable to attack are discharged.

EXERTION.—A. Smith says that severe exertion after decompression predisposes to attack. This is to be expected, for the exertion may force the air bubbles in the blood vessels out of harmless into harmful places. We have brought on attacks of convulsion by massaging the abdomen of rapidly decompressed animals. The monkey in experiment 4 died after struggling.

VENTILATION.—E. H. Snell lays great stress on the good results which follow free ventilation of caissons. He says, "An increase of CO_2 from .04% to .1% at 30 lbs. pressure is the forerunner of much illness."

In one of the Blackwall caissons where the pressure was 25 to 35 lbs. illnesses were occurring at the rate of seven a day. The men were working at the bottom of the caisson; the air supply pipe opened near the roof and the air escaped again through the roof. The supply pipe being lengthened, the illnesses at once dropped to an average of 1 in 2 days.

The following table has been compiled by Snell to illustrate the effect of increased ventilation.

Caisson I. Pressure +25 to 35 lbs.

Cu. ft. of air per man per hr.	No. of days.	Cases of illness.	Illnesses per 100 days.
Below 4,000	13	41	315.5
4,000 to 8,000....	26	78	300.0
8,000 " 12,000....	10	8	80.0
Above 12,000.....	12	4*	33.3

*Only 2 or 3 men were in the caisson on the days when these illnesses occurred, and so the total volume of air supplied to the caisson was reduced, i. e., the air supplied per man was high, but low per caisson.

In other tables Snell seeks to prove that a ventilation of over 12,000 cu. ft. per man abolishes illness. He points out that candles smoke in compressed air, but cease to do so if put within a lamp chimney, so as to increase the draft. As the velocity of diffusion of a gas varies inversely as the sq. root of the density he attributes the smokiness of the candle to the slow diffusion of the products of combustion.

Snell suggests that an increase of CO_2 from .04 to .1% may actually be the cause of caisson illness and that CO_2 may be the gas which in particular is set free in the blood decompression. There is no evidence that this amount has the slightest toxic effect.

At Brooklyn caisson with .33% CO_2 was found on analysis, which at 3 atm. gives .99% atm. CO_2. At Blackwall with .1% CO_2 and at Brooklyn with .33% CO_2 the extra CO_2 would cause a slightly increased depth of breathing and thus practically no effect on the composition of the alveolar air in contact with the blood. This, at least, would seem to follow from experiments recently communicated to the Physiological Society by Haldane and Priestley.

We cannot suppose that a small percentage of CO_2 in the air would contribute in any way to the setting free of CO_2 bubbles on decompression. It is true that Paul Bert found 15% CO_2 and 85% N in the air obtained from the heart of animals killed by rapid decompression. When blood is exposed to air it gives off CO_2 owing to the very low partial pressure of this gas in the atmosphere. Similarly, when nitrogen gas is set free in the heart, some CO_2 will diffuse out and Bert found some traces of oxygen. Bert's analyses of blood gases show that the CO_2 in the arterial blood is, if anything, lessened under the influence of compressed air, and our results confirm Bert.

Hunter notes that the most dangerous times in the Forth Bridge caisson were (1) when soft wet silt was being removed, (2) when concreting was going on. It must be borne in mind that the presence of traces of a toxic gas such as H_2S is dangerous in compressed air, owing to the increase in the partial pressure of such impurities. In the case of CO the increase in partial pressure will be balanced by that of oxygen. But the CO might produce its effect on decompression. The caissons become fouled with the excretions of the workmen, and it is very needful that proper earth-pails should be provided.

As matters stand at present it is not easy to explain Snell's ventilation results, and it is urgently required that they should be confirmed.

Increased rate of ventilation has not seemed to affect our animals in regard to CO_2 output.

SELECTION OF WORKERS.—From the records of caisson sickness and from our experimental results we conclude that the men selected for high pressure work should be small men, of spare and wiry habit, not older than 20 to 25. The men should be total abstainers and abstemious in all their habits.

The men should all be tested at low pressure first, and those who suffer from symptoms should be discharged.

RULES FOR CAISSON WORK.—The following we consider to be safe rules for working:

The longer the shift, the greater is the saturation of the body fluids with gas, and the slower therefore should be the decompression.

The higher the pressure, the shorter should be the shift, and the longer the decompression.

We suggest the following times as safe:

Atmosphere.	Pounds.	Shift.	Decompression period.
+2	30	4 hrs.	30 mins. to 1 hr.
+3 to 4	45 to 60	4 "	1 to 2 hrs.
+5	75	1 "	1 to 2 hrs.
+6 to 7	90 to 105	30 mins. to 1 hr.	2 hrs.

To prevent men breaking the rules the decompression chamber should be provided with one cock only, which will allow decompression to take place in the given time. A separate lock should be provided for the rapid passage of material. The decompression chamber must be artificially warmed, so that the temperature does not fall below 60°F., and it must be thoroughly ventilated during decompression.

The ventilation of the caisson or diving apparatus should be very free, and the temperature of the air should be about 60°F. The men should remain quiet for an hour or so after decompression and be recompressed on any sign of sickness. Paul Bert recommends that oxygen be supplied to the decompression chamber in order to hasten the diffusion of nitrogen. This is no doubt a means by which the period of decompression migh be shortened, but it introduces the danger of oxygen poisoning.

We are of opinion that by proper choice of men and regulation of the shift and decompression period, work could be carried out without loss of life at a depth of even 200 ft., i. e., about 7 atm., or +100 lbs. pressure.

SUMMARY.

(1) Compressed air at and above 4 to 5 atm. lessens the CO_2 output, and lowers the body temperature.

(2) Oxygen at and above 1 atm. has the same effect. It is a sign of oxygen poisoning.

(3) Compressed air at 10 atm. is more damaging, at least to small animals, than oxygen at 2 atm.

(4) Compressed air increases the loss of body heat both because it is a better conductor, and because it is saturated with moisture.

(5) The saturation of the air with moisture does not prevent evaporation from the body because the skin temperature is above that of the air. The wet air by damping fur or clothes causes loss of heat.

(6) Highly compressed air may possibly interfere with the diffusion of CO_2 from the alveolar air, and may, owing to increased friction, hinder the passage of air in and out of the air-tubes.

(7) The nitrogen output is not altered in any noteworthy degree by exposure for six hours to 8 atm. air.

(8) Inflammation and consolidation of the lungs is produced by exposure to 8 atm. air for about 24 hours. 1½ atm. of pure oxygen has a similar effect. The higher the oxygen tension the more rapidly does the inflammation ensue, e. g., 6 atm. O_2 produces marked congestion in 2 hours.

(9) It does not seem likely that inflammation of the lungs should be produced in the pressures and times of exposure usual in caissons.

(10) Excised frog's hearts, muscles, and nerves are not rapidly poisoned by even 50 atm. O_2. A heart will beat more than an hour exposed to this pressure. The vagus nerve endings appear to be paralyzed by such exposure, while inhibition can be obtained by stimulating the crescent. The thin sartorius muscle is much more easily affected than the gastrocnemius, and soon gives a curve like a fatigue curve.

(11) All animals investigated, vertebrates and invertebrates, are instantly convulsed and killed by exposure to 50 atm. O_2.

(12) Convulsions are frequently produced in vertebrates by exposure to 4 to 5 atm. O_2 while exposure to 6 to 25 atm. O_2 produces dyspnoea and coma, and the convulsive stage does not usually appear. Cleaning movements, salivation, gaping, jerky deep respiration, are symptoms, which precede the convulsions, and coma soon follows them.

(13) We have not observed convulsions with air pressures up to 12 atm. Salivation, dyspnoea, and coma are the symptoms.

(14) The blood-gases increase in compressed air or oxygen according to Dalton's law, but the process of complete saturation of blood and tissues takes some time.

FIG. 1. WOODEN DECK BRIDGE FLOOR WITH FELT WATERPROOFING; CHICAGO & WESTERN INDIANA RY.

E. H. Lee, Chief Engineer; F. W. Bird & Son, East Walpole, Mass., Waterproofers.

(15) The circulation is unaffected mechanically by compressed air.

(16) The cause of caisson sickness is the escape of gas bubbles in the blood vessels and tissue fluids on decompression. An animal exposed for 4 hours to 8 atm. air and quickly decompressed is like an opened bottle of soda-water. The fluids of the body generally effervesce.

(17) The effervescence can be studied in the circulation of the frog's web or bat's wing, the animals being enclosed in a suitable chamber. It takes a little time for the bubbles to grow to an appreciable size.

(18) Recompression causes the bubbles to go into solution, and if applied quickly enough the circulation recommences.

(19) The bubbles after rapid decompression can be seen post-mortem in the blood vessels, in the heart, retinae, aqueous humor, connective tissue spaces, etc. The alimentary canal is blown out with gas. The bubbles produce cyst-like cavities in solid organs, e. g. in the central nervous system, the liver. The cells are compressed round these cysts.

(20) In the case of oxygen an animal may recover after an extraordinary amount of this gas has been set free by rapid decompression. The nerve cells are not killed by the oxygen bubbles, and the animals are convulsed and exhibit hyper-reflex-excitability.

(21) The varying symptoms of caisson sickness are due to the varying seat of the air emboli.

(22) Young men escape caisson sickness owing to the elasticity of their tissues, and greater facility for collateral pathways of circulation.

(23) Animals can be safely exposed to 8 atm. of air for four hours if two hours be spent in gradual decompression. Such exposure can be safely repeated three times a week.

(24) By the choice of suitable men, and proper regulation of the period of compression and decompression, caisson and diver's sickness can be avoided.

WATERPROOFING BRIDGE FLOORS ON THE CHICAGO & WESTERN INDIANA R. R.

The Chicago track elevation work on the Chicago & Western Indiana R. R. involves a great amount of steel girder bridge work on account of the number of streets crossed and the number of tracks. The floor system consists of transverse I-beams resting on the bottom chords of the plate girders and covered with creosoted planking, the joints of which are calked with oakum so as to be watertight. This style of bridge floor was illustrated in our issue of Nov. 12, 1903 (Fig. 7, p. 439), and the construction work is under the direction of Mr. E. H. Lee, Chief Engineer.

For the waterproofing of the floor, a covering of "Hydrex" felt is used, and the present method of laying this is to place it in transverse strips 36 ins. wide, with a lap of 12 ins. for each layer, so as to break joints. No composition is laid between the floor and the first layer, so that warping or twisting of the planks will not affect the covering. Each layer, however, is swabbed with hot "Hydrex" composition, which is also applied where the felt lies against the web and gusset plates of the girders. The felt has a hard but flexible coating so that its fibers will not be injured by the hot application. The composition has an asphaltic base, and no tar is used, for the reason that ordinary tar dries out and becomes brittle. This system of waterproofing is used also for masonry work, and has been specified for the North River tunnel of the Pennsylvania R. R. at New York, as shown by the specifications given in our issue of Oct. 15, 1903. It is manufactured by F. W. Bird & Son, East Walpole, Mass.

FIG. 2. BRIDGE FLOOR MADE WATERPROOF WITH FELT AND COMPOSITION COVERING.

Figs. 1 and 2 show the work in progress and the finished floor. On the waterproofed floor is laid a bed of sand and gravel to absorb and hold the water, and above this is the stone ballast for the ties.

The floor beams are 15-in., 42-lb. I-beam, with 2⅛-in. floor planking; and the minimum distance from top of floor to bottom of tie is 6 ins.

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